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# WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

DISASTER PREVENTION RESEARCH INSTITUTE

Practical demonstration of some available tools for Natech risk assessment, risk mitigation and emergency planning for various types of natural hazards.



13/03/2017

Kyoto University, Uji Campus

Collaborative Research Hub / Building 77 / Room 301



# ***WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT***



Workshop Chairs:  
Ana María Cruz, Kyoto University  
Shin-ichi Aoki, Osaka University



# WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

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## **Images**

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# WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

DPRI, KYOTO UNIVERSITY

## WHAT IS A NATECH ACCIDENT?

A Natech accident is a technological accident triggered by natural hazard events such as earthquakes, floods, storms, lightning, landslides, etc.

In this context, a technological accident is understood as:

- Damage to and hazardous-materials releases from fixed chemical plants.
- Damage to and hazardous materials releases from oil and gas pipelines.

At least 50% of surveyed EU Member States and OECD Member Countries have experienced one or more Natech accidents, sometimes with fatalities and injuries, environmental and/or economic damage.

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# ACKNOWLEDGMENTS

This publication was put together by a group of international experts under the auspice of the Disaster Prevention Research Institute (DPRI), Kyoto University.

Its content reflects the multi-perspective contributions and international experiences presented at Kyoto University, Uji Campus, in March 2017, within the framework of the Workshop on Tools for Natech Risk Management.

We would like to thank the workshop speakers Prof. Kaoru Takara, Director, DPRI, Kyoto University; Prof. Shin-ichi Aoki, Osaka University; Mr. Jaime Pacheco, First Secretary of the Colombian Embassy in Japan; Ms. María Camila Suarez, DPRI; Prof. Felipe Muñoz Giraldo, Universidad de los Andes, Colombia; Dr. Elizabeth Krausmann, Joint Research Centre, European Commission, Italy; Prof. Valerio Cozzani, Università di Bologna, Italy; Prof. Ernesto Salzano, Università di Bologna, Italy; Emeritus Prof. Naomi Kato, Osaka University, Japan; Dr. Tomoaki Nishino, Building Research Institute, Japan; Prof. Mauricio Sánchez, Universidad de los Andes, Colombia; and Dr. Takeshi Komino, CWS, Japan.

We would also like to acknowledge the contribution of the members of the Disaster Risk Management Laboratory (Cruz Lab) to the preparation of this report under the guidance of Prof. Felipe Munoz Giraldo.

The Natech Workshop was partly funded by the Disaster Prevention Research Institute, Kyoto University, for which we are grateful.

About the Disaster Risk Management Laboratory (Cruz Lab):

Our lab is multidisciplinary, integrating skills and knowledge from a variety of disciplines such as engineering, sociology, economics, and disaster risk management (DRM), benefiting synergistically by working in association with local, national and international students, researchers and faculty ([www.natech.dpri.kyoto-u.ac.jp](http://www.natech.dpri.kyoto-u.ac.jp)). Cruz Lab is part of the Center for Disaster Reduction Systems (DRS) at DPRI, Kyoto University. *Its purpose is to promote research and practices to build a safe and resilient society by reducing disaster risks.*

# SUMMARY

The Workshop on Tools for Natech Risk Management was organized and hosted by the Disaster Prevention Research Institute (DPRI) at Kyoto University, Uji Campus, on March 13<sup>th</sup> 2017. The Natech workshop was carried out in an effort to do a hands-on practical demonstration of some available tools for Natech risk assessment, risk mitigation and emergency operations planning for various types of natural hazards. The workshop was attended by participants from 12 countries, including experts, students and stakeholders involved in Natech disaster risk reduction and similar topics.

The event included talks on available Natech tools, their strengths, implementation and development of case studies. A discussion of key elements and needs in the Natech context was the way to conclude the workshop. Identification of priorities, gaps and future research road map were the main outcomes of the event.

# DESCRIPTION AND OPENING CEREMONY



On 13<sup>th</sup> March 2017, the Disaster Prevention Research Institute (DPRI, Kyoto University) hosted the Workshop on Tools for Natech Risk Management. Participants included representatives from Afghanistan, Bulgaria, China, Colombia, Egypt, Germany, Japan, India, Italy, Mexico, South Korea and Philippines (see Annex 4). The event was opened by the Director of the Disaster Prevention Research Institute, Prof. Kaoru Takara; Prof. Ana Maria Cruz, DPRI, KU; Prof. Shin-ichi Aoki, Osaka University; and Mr. Jaime Pacheco, First Secretary of the Colombian Embassy in Japan. Prof. Takara highlighted Natech's place in the Sendai framework for Disaster Risk Reduction.

During the opening ceremony speakers remarked the fact that Natech is a very recent concept and mentioned the need to better understand its complex accidental dynamics within interdisciplinary teams. They encouraged researchers to continue working towards prevention, mitigation and protection measures. The Colombian Embassy manifested their interest to support the development of research on Natech issues.



# SECTION 1

## State of the Art in Natech Risk Management

*María Camila Suarez, DPRI; Felipe Muñoz Giraldo, Universidad de los Andes Colombia; Ana Maria Cruz, DPRI*

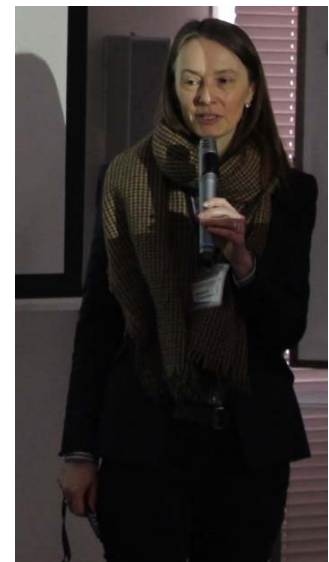
This presentation was given by María Camila Suarez, a Ph.D. student at DPRI. She presented the state of the art in Natech Risk Management based on two stages of analysis. The first stage focused on a review of the literature concerning potential Natech accidents, mainly an apriori approach, and the second stage focused on a review of the literature concerning past Natech events, a posteriori approach. Classification by hazards and different types of analysis for the methodologies proposed so far has been conducted. The findings demonstrated the necessity for further research and outlined the way forward on this relatively recent topic.



## RAPID-N: Earthquake Natech Risk Assessment

*Elisabeth Krausmann, Joint Research Centre, European Commission, Italy*

RAPID-N is a web based semi-quantitative tool for Natech risk assessment and mapping developed by the Joint Research Centre (JRC) of the European Commission. Rapid-N includes an integrated methodology able to analyze Natech risks by estimating the natural-hazard severity (e.g. earthquake) at a hazardous site, the damage caused by the natural hazard using fragility curves, and the consequences of the damage. The results give an overview of the impacted area around the accident site with respect to heat radiation and toxic concentrations. The JRC is the science body of the European Commission. Its mandate is to support policy making by providing scientific guidance to the European Commission. Through its activities, the JRC also supports EU Member States and operators in the identification and reduction of Natech risks.



## SECTION 2

## Natech Quantitative Risk Assessment by the ARIPAR software

*Valerio Cozzani, LISES-DICAM, Università di Bologna, Italy*

Natech events are characterized by a high level of complexity. They are categorized among the high impact, low probability events. As a consequence, Quantitative Risk Assessment (QRA) of Natechs is a challenging issue. The ARIPAR-GIS tool was developed under the ARIPAR project, which started since 1988. ARIPAR-GIS considers the impact area, vulnerability centers, demographics, meteorology and a combination of scenarios (e.g. 10,000-200,000 combination of scenarios) to give risk indexes as an output. For each risk source, event and failure trees are used, as well as geographical information. Vulnerability maps of the final scenarios are managed by the software. It has been applied to analyze several Italian industrial areas and it has proved to be a robust tool. The first complete approach to Natech QRA was published in 2007, but it needed a computational tool. As a consequence, ARIPAR-GIS has now been modified to implement a specific method for Natech QRA, allowing the calculation of the specific contribution of Natech scenarios to the overall industrial risk figures.



## Quantitative Assessment of Earthquake and Tsunami Natech scenarios

*Ernesto Salzano, Università di Bologna, Italy*

The complexity of Natech scenarios is such that Quantitative Risk Assessment requires a complex, multi-disciplinary analysis, involving several engineering and natural science disciplines. Under the STREST project, the fishbone diagram of industrial risk analysis was adopted and natural hazards and their interactions incorporated in order to analyze a case study of a refinery in Milazzo, Italy. Earthquake and Tsunami were the natural hazards considered. Thus, Probabilistic Seismic and Tsunami Hazard Analysis (PSHA) were developed. Results were obtained using the Risk Curves/Effect TNO tool. The results given by the tool are based on available standards for vulnerability and for consequence analysis. Therefore, they can only be used for comparative purposes and as preliminary inputs for land use planning. It was concluded that the general complexity of Natech scenarios, which includes natural hazard analysis, is partially reduced by the similarities industrial facilities share worldwide and the availability of data associated to them .



## SECTION 3



# Oil and Gas Releases during Large Earthquakes and Tsunami

*Shin-ichi Aoki and Naomi Kato, Osaka University, Japan*

Osaka bay is exposed to several hazards such as floods, earthquakes, tsunami and storm surge. The consequences of oil and gas releases due to a large earthquake and associated tsunami in Osaka Bay represent a high risk for industrial facilities and neighboring communities. Thus, a research initiative for Disaster Prevention of Petrochemical Complexes (industrial parks) which includes the case study of the Sakai-Senboku industrial area, has been presented. Onshore and offshore propagation of damages were considered, although consequences and impacts were mostly present offshore. Numerical simulations of tsunami propagation and dispersion of spilt oil, including oil spill from storage tanks due to sloshing using Meshless Moving Particle Semi-implicit (MPS) method were developed. Furthermore, laboratory experiments on tsunami-induced hydrodynamic forces at the harbor and 2D experiments on wave forces acting on a tank have been used in order to validate a proposed model, considering similarities and scale effects. Community-engagement initiatives have also been carried out exchanging opinions with residents near the industrial park areas. Finally, countermeasures that are being developed such as reduction of tsunami energy by flexible pipes and blocking tsunami by an earth bank were presented.



## Development of Simulation Tool for Fire Spread on Floating Oil in Tsunamis

*Tomoaki Nishino, Building Research Institute, Japan*

The tsunami following the 2011 Great East Japan Earthquake caused spreading of fires at Kesenuma Bay. A large quantity of oil, which had been spilled from destroyed oil tanks, contributed to such tsunami-induced fires. Some of the fires ignited tsunami refuge buildings, and people who had escaped to the buildings from the tsunami were exposed to the fires. In addition, the fires spread to forests, resulting in wildfires involving 231 ha. These facts have raised concern among people whom must evacuate for future tsunamis of the risk from tsunami-induced fires. Nevertheless, adequate measures have not yet been taken in recent disaster prevention planning, because there is no method for predicting the big picture of tsunami-induced fires.

The Building Research Institute has been developing a computational model for fire spread on floating oil in tsunamis. The model regards the spreading fires on the sea as an assembly of burning floating oil particles, and tracks the burning zone by predicting the locations and combustion behaviors of individual particles in time series. The spreading fires on Kesenuma Bay were numerically analyzed. As a result, it was concluded that the qualitative trend of the fire spread was well predicted by the model, compared with the actual conditions which were determined from film records and survey data.



## Landslide and Pipeline Natech Risk Assessment Tool

*Mauricio Sánchez and Felipe Muñoz Giraldo, Universidad de los Andes, Colombia*

A quantitative-mechanistic model for assessing the probability of failure along pipelines due to their interaction with landslides, named GeoRisks was presented. The objective was to develop an integrated model to evaluate the risk of pipeline subjected to multiple natural hazards. The importance of managing problem complexity was considered. Topography, geotechnical information, hydrology, and pipeline information have been considered in the analysis. Cost analysis was also presented with a particular focus on cost-efficient design. Finally, criteria for risk management and structured hierarchical decision processes have been identified.



## SECTION 4

## Radiation Measurement for Protection of Children in Fukushima

*Takeshi Komino, CWS, Japan*

This presentation focused on the important question of how to mitigate nuclear-related risks analyzing the position of the government and providing real-time data. The presentation showed that under the Technical Hazards Working Session of the Sendai Framework, a call for transparent disclosure of risks was made. The question on “how are the lessons from Fukushima being used to mitigate future losses?” was the starting point to develop the project for Sharing Lessons and Protecting the Vulnerable communities. As a result, a method that is used to measure individual levels of radiation in Fukushima was developed. The tool has been used to identify radiation hotspot, particularly in schools and other public areas which then leads to on-the-spot decontamination efforts led by local government.

The NGO CWS Japan operation pillars are related to humanitarian development assistance, advocacy and capacity building, and it works with a NGO called Shalom on the project presented.



## Discussion and Wrap-up Panel Session

Chair: Ana Maria Cruz

Panelists: Elisabeth Krausmann, Ernesto Salzano, Valerio Cozzani, Takeshi Komino, Tomoaki Nishino, Naomi Kato, Felipe Muñoz, Mauricio Sánchez.

The discussion and wrap-up panel session was the opportunity to evaluate overall awareness concerning Natech risks, assess research achievements and gaps, and delineate the main conclusions from the Workshop. The panelists agreed that awareness concerning Natechs risks has increased. It was also mentioned that there is a need for interaction between people from different disciplines and exchanges within different geographical areas in order to provide guidance for industrial plants and local governments. As a consequence, integrated and useful models are needed to help decision makers take the right decisions. However, several issues remain unsolved such as how to use and interpret model results to adequately inform decision making.

All the panelists agreed that uncertainty characterization is a central issue. It needs to be further addressed and explained, in order to have models that serve a purpose and can be implemented by authorities and stakeholders. One of the panelists noted “Models may not yet address uncertainties and are not yet dynamic”. But the question on how to include changeability, adaptability and flexibility in these models is still not resolved. For example, issues related to infrastructure deterioration and depreciation over time are not yet incorporated in current risk assessment models.

The importance of estimating economic losses from Natech accidental scenarios and the need to have more precise estimation tools which consider direct and indirect damages and losses was highlighted.

Another aspect that was discussed during the session was data availability. Several panelists manifested the need to have databases based on detailed descriptions of past accident scenarios, and agreed efforts to promote data sharing and recording is crucial for lessons learning. Another problem identified is the need to work towards improved risk communication and disclosure of risk information by industry to potentially affected communities. Thus, a call was made for inclusion of more social science approaches and risk communication fields in future Natech studies.

One of the participants noted that Natech risk management focuses on industrial aspects and exposure, but that it is also a risk governance problem. Risk management is in the hands of industries or through policies by government officials. Will power from

government officials is needed. In developing countries, the problems are even greater due to lack of economic and human resources, and so on. The need for an international standard for Natech risk management, and the importance of constructing an international framework on Natechs was noted. In this context, the question concerning “What are key criteria needed for a Natech performance rating system?” was raised. The answers provide by the panelists and participants touched upon several issues including:

- Awareness about the problem
- Identification of exposure to hazards
- Knowledge creation (chemicals, quantities, etc.)
- Definition of natural hazard and level of risk
- Facilities should look at events beyond design level
- Emergency response (not captured by QRA)
- Emergency planned made by public authority.
- Early warning /forecasting in case of storms, flood etc.
- Incentives for companies
- Indicators for the relation between land use planning and governance.





# Annexes

Annex 1:

Group Photo

# PARTICIPANTS



**Standing, left to right (First row):** Ana Maria Cruz, Kaoru Takara, Valerio Cozzani, Angelica Baylon, Sandhya Babel, Jaime Pacheco, Ma. Camila Suarez, Marina Hamidzada, Luiyi Zhang.

**Standing, left to right (Second row):** Takeshi Komino, Dewi Dimyati, Ahmed Ibrahim, Ernesto Salzano, Shin-ichi Aoki, Shinichi Yamamoto, Horikomi Kaori, Felipe Muñoz.

**Standing, left to right (Third row):** Bonjun Koo, Daniel Cardoso, Atsushi Aoyama, Alexander Guzman, Elizabeth Krausmann, Toma Stoyanov, Uta Reichardt, Mauricio Sánchez, Hirokazu Tatano, Tomoaki Nishino, Irasema Alcantara, Giuseppe Aliperti, Hitomu Kotani.

Annex 2:

Program

**Collaborative Research Hub, Room 301**  
**Building 77, Uji Campus, Kyoto University**  
**March 13, 2017**

	9:00 - 9:20	Opening ceremony <i>Kaoru Takara, Director, DPRI, KU</i> <i>Ana María Cruz, DPRI, KU</i> <i>Shin-ichi Aoki, Osaka University</i> <i>Jaime Pacheco, First Secretary of the Colombian Embassy in Japan</i>
<b>Chair:</b> <b>Ana María Cruz</b>	9:20 - 9:40	State of the Art in Natech Risk Management <i>María Camila Suarez, DPRI; Felipe Muñoz Giraldo, University of Andes, Colombia; Ana María Cruz, DPRI</i>
	9:40 - 10:20	RAPID-N: Earthquake Natech Risk Assessment <i>Elizabeth Krausmann, Joint Research Centre, European Commission, Italy</i>
10:20 - 10:40		<b>Coffee Break</b>
<b>Chair:</b> <b>Shin-ichi Aoki</b>	10:40 - 11:20	Natech Quantitative Risk Assessment by the ARIPAR software <i>Valerio Cozzani, University of Bologna, Italy</i>
	11:20-12:00	Quantitative Assessment of Earthquake and Tsunami Natech scenarios. <i>Ernesto Salzano, University of Bologna, Italy</i>
12:00 - 13:30		<b>Lunch</b>
<b>Chair:</b> <b>Felipe Muñoz</b>	13:30 - 14:10	Oil and gas releases during large earthquakes and tsunami <i>Shin-ichi Aoki and Kato Naomi, Osaka University, Japan</i>
	14:10 - 14:50	Damage and Effects Caused by Tsunami Fires <i>Tomoaki Nishino, Building Institute, Japan</i>
	14:50 - 15:30	Landslide and Pipeline Natech Risk Assessment Tool <i>Mauricio Sánchez and Felipe Muñoz Giraldo, U. Andes, Colombia</i>
15:30 - 15:50		<b>Coffee Break</b>
<b>Chair:</b> <b>Irasema Alcantara</b>	15:50 - 16:30	Tool for Assessment of Radiation Hotspots <i>Takeshi Komino, CWS, Japan</i>
<b>Chair:</b> <b>Ana María Cruz</b>	16:30 - 17:45	Discussion and Wrap-up Panel Session Panelists: <i>Elizabeth Krausmann, Ernesto Salzano, Valerio Cozzani, Takeshi Komino, Tomoaki Nishino, Naomi Kato, Felipe Muñoz, Mauricio Sánchez</i>
17:45 - 18:00		Closing Ceremony

Annex 3:

Presentations

# State of the art in Natech Risk Management

## Workshop 2017 – Kyoto

**María Camila Suarez**  
**Prof. Ana María Cruz**  
**Prof. Felipe Muñoz Giraldo**  
 Research Center for Disaster Reduction Systems  
 DPRI, Kyoto University  
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## Content

1. Introduction
2. State of the art in Natech risk management
3. Conclusions

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## Content

1. Introduction.
2. State of the art in Natech risk management.
3. Conclusions.

3

Earthquake of magnitude 7.4 Mw  
 Turkey earthquake 1999



Intentional release of 200,000 kg of hazardous anhydrous ammonia

Leakage of 6.5 million kg of toxic acrylonitrile into air, soil, and water

Liquid petroleum gas leakages and oil spills at the port terminal at an oil refinery

Hurricane Katrina 2005



Release of over 30,000m<sup>3</sup> of oil

Soil contamination

More than US\$100 billion in damage estimated.

Earthquake of magnitude 9.0 Mw & Tsunami (400 km<sup>2</sup> of land)  
 Great East Japan Earthquake-Tsunami 2011



190,000 buildings damaged (45,700 totally destroyed).

Worst nuclear power accident in Japan's history.

Industrial Production Index dramatically decreased by 15.5%. (Decline in global automobile production).<sup>4</sup>

Earthquake of magnitude 7.4 Mw  
 Turkey earthquake 1999



Hurricane Katrina 2005



Earthquake of magnitude 9.0 Mw & Tsunami (400 km<sup>2</sup> of land)  
 Great East Japan Earthquake-Tsunami 2011



Steinberg, L. J., and A. M. Cruz (2004).

Cruz, A. M., and E. Krausmann (2008).

Krausmann, E. and A. M. Cruz (2013).

5

## Introduction

*A priori*  
 approach



*A posteriori*  
 approach



Introduction

*A priori* approach

*A posteriori* approach

Introduction

Descriptor NATECH Journals

Title Keywords 1823-2017 Abstract

Introduction

**Selection criteria**

- Natural hazards and/or technological accidents involved.
- Natech scenarios.
- Hazardous materials release.

Introduction: classification

Natural hazard

Earthquake	Floods	Lightning
Storms	Tsunami	Hurricane
Volcanic eruptions	Landslides	Extreme Temp.
Wildfires	Droughts	Multi-hazard and crosscutting

Introduction: classification

Approach of the methodology

Introduction: classification

Type of analysis developed.

Hazard Assessment	Risk Analysis	Risk Assessment
Prevention and Mitigation	Business Continuity Planning (BCP) and R <sup>3</sup> (Reconstruct, Recovery, Restoration)	

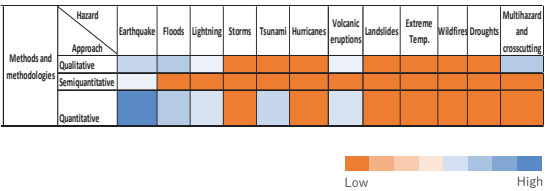
# Content

- 1. Introduction.
- 2. State of the art in Natech risk management.
- 3. Conclusions.

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# State of the art in Natech risk management

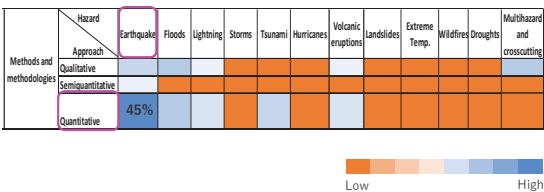
A priori analysis



14

# State of the art in Natech risk management

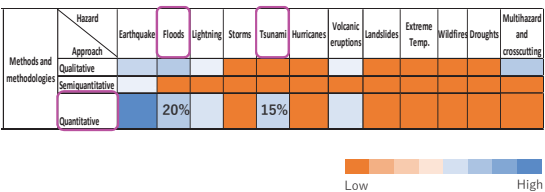
A priori analysis



15

# State of the art in Natech risk management

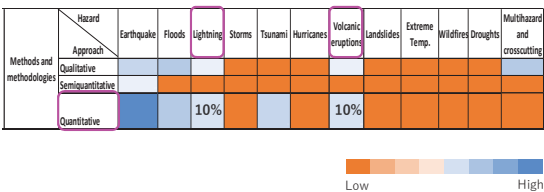
A priori analysis



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# State of the art in Natech risk management

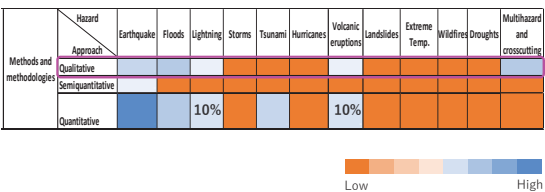
A priori analysis



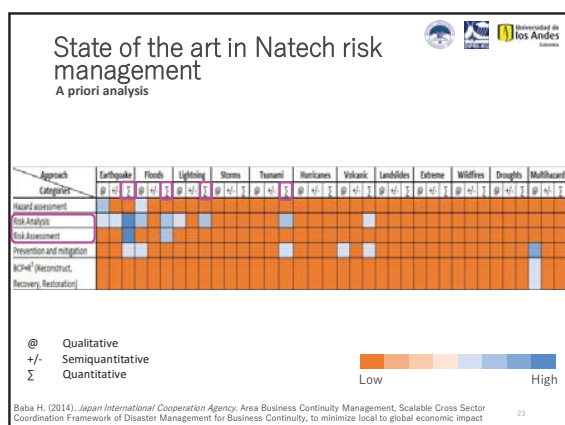
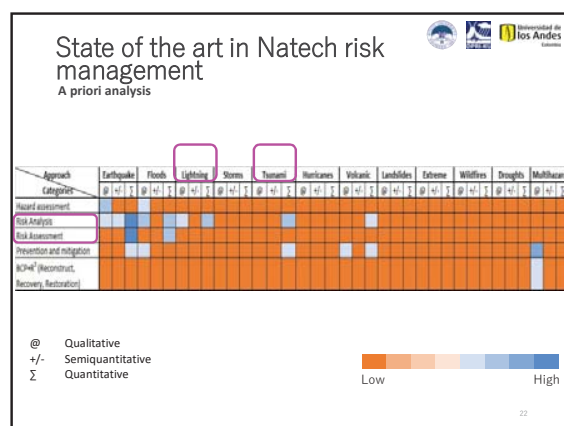
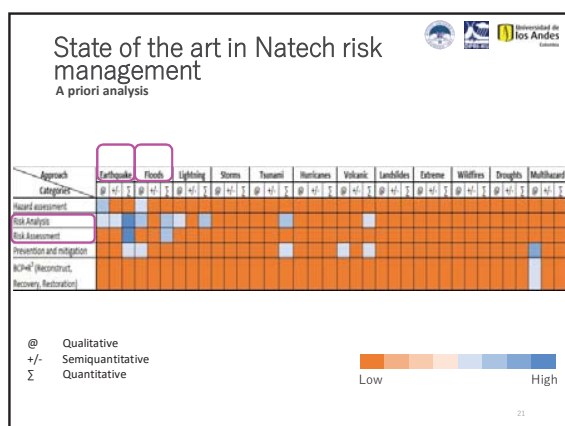
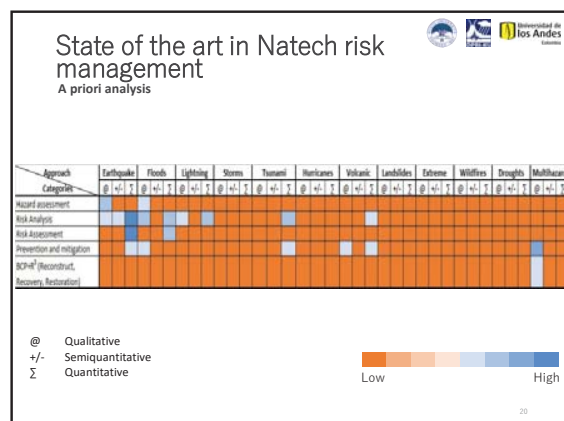
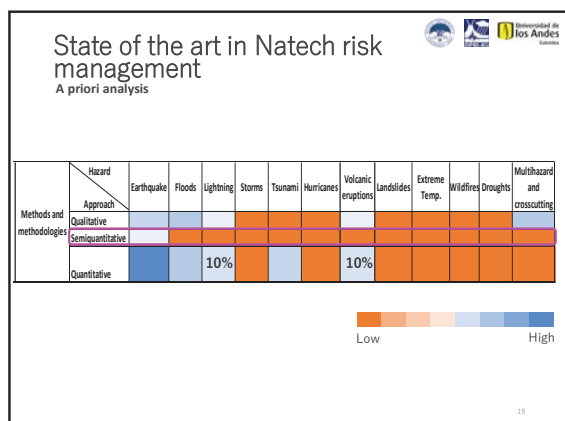
17

# State of the art in Natech risk management

A priori analysis



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### State of the art in Natech risk management


#### Databases

No.	Databases and accident reports	Acronym	Information available (from-to)	Descriptors
				Flood Earthquake Lightning Storms Tsunami Hurricanes Volcanic eruptions Landslides Extreme Wildfires Droughts Natural phenomena NAT-TECH
1	High Pressure Gas Safety Institute Japan	CHS	2005- Present	
2	National Response Centre	NRC	1950- Present	
3	US Environmental Protection Agency in the ERNS database	ERNS	1986- 1995	
4	Incident Reporting Information System	IRIS		
5	Major Accidents Reporting Systems	MAARS	1982- Present	
6	Toxic-Release Inventory database	TRI	1977- 2015	
7	Failure and Accidents Technical Information System	FACTS	1977- 2014	
8	European Strong Motion Database	ESD	1967- 2008	
9	Hazardous Substances Emergency Events Surveillance	HSEES	1993- 2009	
10	Analysis, Research and Information on Accidents database	ARIA	1992- Present	
11	Major Hazard Incident Data Service	MAIDS	2001- 2014	
12	The Accident Database	AD		
13	Association of Bay Area Governments Resilience Program*	ABAG	1990- 1992	
14	Tokyo National Police Agency	NPA	Present	
15	Resilience database	Resilience	2000- Present	
16	nNATECH (Natural Hazard - Triggered Technological Accidents)	n-Natech	Present	
17	The International Disaster Database	Disdat	1900- Present	
18	Pipeline and Hazardous Materials Safety Administration	PHMSA	1970- Present	
19	A large database of earthquake-induced damage for steel and non-steel pipelines	Leuzinger et al	2015- Present	

# State of the art in Natech risk management Databases



No.	Databases and accident reports	Acronym	Information available (from-to)	Descriptors									NATECH
				Flood	Earthquake	Storm	Chemical	Volcanic eruptions	Landslides	Extreme temperature	Wildfires	Drought	
1	High Pressure Gas Safety Institute Japan	KHK	2005- Present										
2	National Response Centre	NRC	1990- Present										
3	US Environmental Protection Agency in the ERNS database	ERNS	1986-1995										
4	Incident Reporting Information System	IRIS											
5	Major Accidents Reporting Systems	eMARS	1982- Present										
6	Toxic Release Inventory database	TRI	1987-2003										
7	Failure and Accidents Technical Information System	FACTS	1997-2014										
8	European Strong Motion Database	ESD	1967-2008										
9	Hazardous Substances Emergency Events Surveillance	HSEES	1993-2009										
10	Analysis, Research and Information on Accidents database	ARIA	1992- Present										
11	Major Hazard Incident Data Service	MHIDAS	2001-2014										
12	The Accident Database	TAD											
13	Association of Bay Area Governments Resilience Program*	ABAG	1990-1992										
14	Japan National Police Agency	NPA	Present										
15	RigLogix database	RigLogix	2000- Present										
16	eNATECH (Natural Hazard - Triggered Technological Accidents)	e-Natech	Present										
17	The International Disaster Database	Emdat	1900- Present										
18	Pipeline and Hazardous Materials Safety Administration	PHMSA	1970- Present										
19	A large database of earthquake-induced damage for steel and non-steel pipelines	Lanzano et al	2015- Present										25



# State of the art in Natech risk management Databases

No.	Databases and accident reports	Acronym	Information available (from-to)	Descriptors										NATECH	
				Flood	Earthquake	Storm	Lightning	Volcanic eruptions	Landslides	Extreme temperature	Wildfires	Drought	Natural phenomena		
1	High Pressure Gas Safety Institute Japan	KHK	2005- Present												
2	National Response Centre	NRC	1990- Present												
3	US Environmental Protection Agency in the ERNS database	ERNS	1986-1995												
4	Incident Reporting Information System	IRIS	1982- Present												
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7	Failure and Accidents Technical Information System	FACTS	1997-2014												
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16	eNATECH (Natural Hazard - Triggered Technological Accidents)	e-Natech	Present												
17	The International Disaster Database	Emdat	1900- Present												
18	Pipeline and Hazardous Materials Safety Administration	PHMSA	1970- Present												
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# State of the art in Natech risk management Databases

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19	A large database of earthquake-induced damage for steel and non-steel pipelines	Lanzano et al	2015- Present									27

### State of the art in Natech risk management Databases

No.	Database	Acronym	Usage
1	National Response Centre	NRC	
2	Failure and Accidents Technical Information System	FACTS	
3	Major Hazard Incident Data Service	MHIDAS	
4	Major Accidents Reporting Systems	eMARS	
5	Analysis, Research and Information on Accidents database	ARIA	
6	The Accident Database	TAD	
7	High Pressure Gas Safety Institute Japan	KHK	
8	US Environmental Protection Agency in the ERNS database	ERNS	
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13	Japan National Police Agency	NPA	
14	RigLogix database	RigLogix	
15	Pipeline and Hazardous Materials Safety Administration	PHMSA	
16	A large database of earthquake-induced damage for steel and non-steel pipelines	Lanzano et al	
17	Association of Bay Area Governments Resilience Program	ABAG	
18	eNATECH (Natural Hazard - Triggered Technological Accidents)	e-Natech	
19	The International Disaster Database	Emdat	

### State of the art in Natech risk management Natech Tools

To complete the analysis, some available tools for:

- Natech risk assessment.
- Risk mitigation.
- Emergency operations planning .

For various types of natural hazards were included.

### State of the art in Natech risk management Tools (Natech + Others)

27 Tools included

- Risk communication tools.
- Preparedness tools
- Emergency response tools
- Modeling and simulation tools

Developed to support needs and close gaps in risk assessment, mitigation and control measures in the Natech context.

## State of the art in Natech risk management

### Natech Tools

No.	Tool name	Approach
1	<a href="#">Advanced Disaster Management Simulator (ADMS)</a>	Emergency Management Simulation
2	<a href="#">Guardian Centers</a>	Training in natural and manmade disasters
3	<a href="#">The Finding Individuals for Disaster and Emergency Response (FINDER)</a>	Natural phenomenon (earthquakes and avalanches)
4	<a href="#">Himada (Catastrophe modeling)</a>	Probabilistic multi-hazard risk assessment
5	<a href="#">SNOWPACK</a>	Multi-purpose snow and land-surface model
6	<a href="#">RAPID-N</a>	Natech risk mapping
7	<a href="#">JANUS</a>	Preliminary Assessment of Natech Risk in urban areas.
8	<a href="#">TRAS 310 Technical Rules on Process Safety (TRAS)</a>	Precautions and Measures Against the Hazard Sources Precipitation and Flooding
9	<a href="#">TRAS 320</a>	Precautions and Measures Against the Hazard Sources Wind, Snow Loads and Ice Loads
10	<a href="#">TRAT-GIS</a>	Quantitative risk assessment computational tool applied to the land transport of dangerous goods
11	<a href="#">Tsunami-Induced Fire Spread Simulation</a>	Tsunami consequences
12	<a href="#">Landslide and pipeline Natech Risk Assessment Tool</a>	Quantitative-mechanistic model for assessing the probability of failure along pipelines due to their interaction with landslides
13	<a href="#">ARIPAR GIS - Software Tool for Area Risk Assessment and Management</a>	Quantitative area risk assessment tool to evaluate the risk from major accidents in industrial areas where hazardous substances are stored, processed and transported.
14	<a href="#">Tool for Assessment of Radiation Hotspots</a>	Assessment of radiation hot spot using Hot Spot Finder and linking it to decontamination efforts by local authority

## State of the art in Natech risk management

### Natech Tools

No.	Tool name	Approach
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5	<a href="#">SNOWPACK</a>	Multi-purpose snow and land-surface model
6	<a href="#">RAPID-N</a>	Natech risk mapping
7	<a href="#">JANUS</a>	Preliminary Assessment of Natech Risk in urban areas.
8	<a href="#">TRAS 310 Technical Rules on Process Safety (TRAS)</a>	Precautions and Measures Against the Hazard Sources Precipitation and Flooding
9	<a href="#">TRAS 320</a>	Precautions and Measures Against the Hazard Sources Wind, Snow Loads and Ice Loads
10	<a href="#">TRAT-GIS</a>	Quantitative risk assessment computational tool applied to the land transport of dangerous goods
11	<a href="#">Tsunami-Induced Fire Spread Simulation</a>	Tsunami consequences
12	<a href="#">Landslide and pipeline Natech Risk Assessment Tool - GeoRisk</a>	Quantitative-mechanistic model for assessing the probability of failure along pipelines due to their interaction with landslides
13	<a href="#">ARIPAR GIS - Software Tool for Area Risk Assessment and Management</a>	Quantitative area risk assessment tool to evaluate the risk from major accidents in industrial areas where hazardous substances are stored, processed and transported.
14	<a href="#">Tool for Assessment of Radiation Hotspots</a>	Assessment of radiation hot spot using Hot Spot Finder and linking it to decontamination efforts by local authority

## State of the art in Natech risk management

### Other Tools

No.	Tool name	Approach
1	<a href="#">Global Platform for Disaster Risk Reduction</a>	Disaster Risk Reduction
2	<a href="#">International Search and Rescue Advisory Group (INSARAG)</a>	Earthquakes
3	<a href="#">Global Environments Network (GEN)</a>	Seeks solutions to environmental and social problems
4	<a href="#">Real-Time Wireless Sensor Network for Landslide Monitoring</a>	Landslides
5	<a href="#">STOP DISASTERS! Disaster simulation game.</a>	Natural disasters
6	<a href="#">Hepal 2015 Earthquakes</a>	Characterising the post-seismic behaviour of damaged slopes
7	<a href="#">JANNH - the Tsunami and earthquake fighter</a>	Tsunami
8	<a href="#">PreventionWeb - Information needs of the DRR community</a>	Multihazard Disaster Risk Reduction
9	<a href="#">Flood Resilience Portal</a>	Flood
10	<a href="#">Practical Action</a>	App used as a Technical Information Service Rebuilding in the Aftermath of an Earthquake Seismic Resistant Retrofitting for Buildings
11	<a href="#">Missing map project</a>	Map up of vulnerable areas before the disaster occurs
12	<a href="#">Flash Environmental Assessment Tool (FEAT)</a>	First aid impact assessment and response prioritization tool, aimed to be used immediately after a chemical incident anywhere in the world.
13	<a href="#">The Hazard Identification Tool (HIT)</a>	Support tool for first responders to identify and address secondary environmental risks as early as possible.

## Content

1. Introduction.
2. State of the art in Natech risk management.
3. Conclusions.

## Conclusions

- This is a first approach which uses a small sample of literature to have an outlook of the state of the art in Natech Risk Management considering specific works which explicitly refer to Natechs.
- There is an increase interest of researchers and industries in understanding the dynamics and effects of storms, hurricanes, tsunamis, landslides and droughts.
- More methods that lie between the quantitative and qualitative approaches are urgently needed as they may be less time consuming and less expensive, while still providing some quantitative measure.

## Conclusions

- This is a first approach which uses a small sample of literature to have an outlook of the state of the art in Natech Risk Management considering specific works which explicitly refer to Natechs.
- There is an increase interest of researchers and industries in understanding the dynamics and effects of storms, hurricanes, tsunamis, landslides and droughts in the industry and community.
- More methods that lie between the quantitative and qualitative approaches are urgently needed as they may be less time consuming and less expensive, while still providing some quantitative measure.
- Some available databases have started to include Natech as keyword and Natech accidents among their records.
- More area wide methodologies and tools are needed in order to address the consequences beyond the fence line, and include neighboring communities in the Natech risk management context.<sup>25</sup>

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## State of the art in Natech Risk Management

### Workshop 2017 – Kyoto

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### JRC activities

**Objective:**  
→ Support the EU Member States and operators in the identification and reduction of Natech risk

**Stakeholders:**  
→ EU Member States, candidate and neighbour countries, third countries; European Commission Services; OECD, UNEP/OCHA, UNISDR

**Activities:**  
→ Accident analysis and guidance on Natech RR  
→ Risk analysis tools  
→ Training

### JRC activities

**Accident analysis and guidance**

- Identification of vulnerable equipment (*fixed, pipelines, offshore*), scenarios and consequences (earthquakes, floods, lightning, hurricanes)
- Site surveys for Natech damage assessment (Japan, China) & statistical analysis, lessons learning
- Natech accident database: **eNatech**  
<http://enatech.jrc.ec.europa.eu>

**Risk analysis tools**

\*Framework for Natech risk assessment and mapping: **RAPID-N**  
<http://rapidn.jrc.ec.europa.eu>

**Training**

### JRC activities

**Natech Risk Mapping**

- Natech risk maps are considered a high priority need for:
  - Identification of Natech-prone areas (land-use planning)
  - Emergency-response planning
- Hardly any Natech risk maps exist in the EU/OECD
  - Simple overlay of natural hazards and industrial facilities
  - Do not consider site-specific features
    - Expected release scenarios
    - Existing safety measures

→ Development of a unified Natech risk assessment and mapping methodology and implementation as a software tool

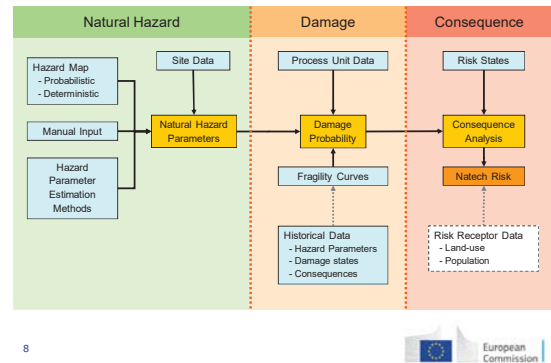
## Rapid-N Natech Risk Assessment & Mapping Framework

- Integrated methodology
  - **Natural Hazard + Accident**
- Rapid assessment
  - **Local and regional analysis**
- Publicly available
  - **Multilingual web service**
- User friendly application
  - **Easy and quick data entry**
  - **Visualization**
- Collaborative environment



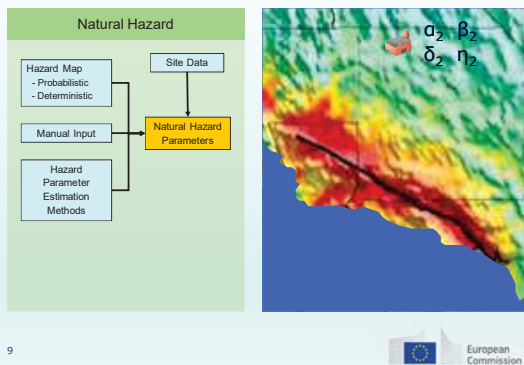
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## Methodology



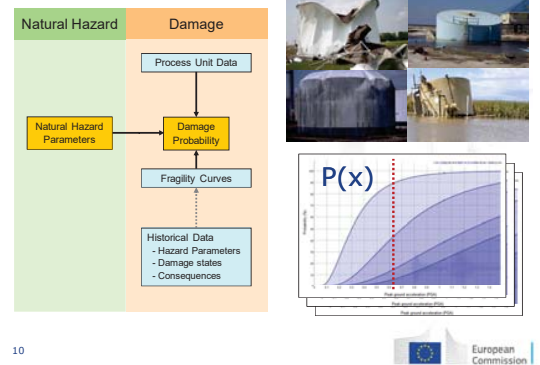
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## Methodology



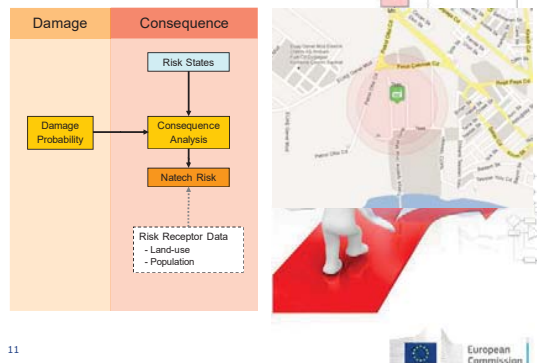
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## Methodology



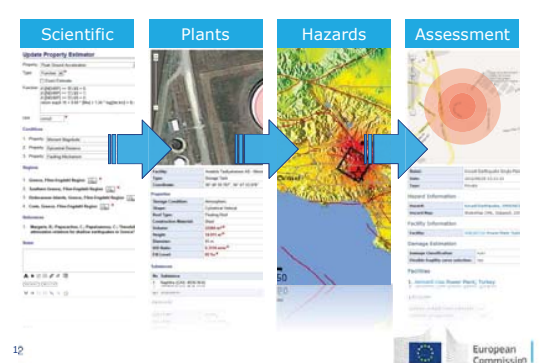
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## Methodology



11

## Modular Structure



12

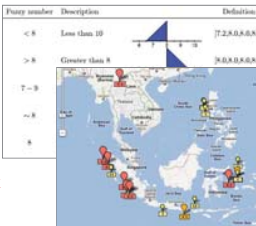


## Scientific Tools Module

- Fuzzy arithmetic
- Automated unit conversion
- Statistics and curve-fitting
- Mapping
  - Google Maps
  - GIS analysis
- Reference management


### Property Estimation Framework

- Minimize data requirement
- Increase flexibility
  - No hard-coded functions



## Property Estimation Framework

- Properties
  - Natural hazard: e.g. PGA
  - Site: e.g. Soil class
  - Facility: e.g. Capacity
  - Process unit: e.g. Volume
  - Substance: e.g. Density
- Data
  - Numerical (with unit)
    - e.g. 10 m<sup>3</sup>, 1.5 m/s
  - Tabular
    - e.g. Atmospheric, Pressurized

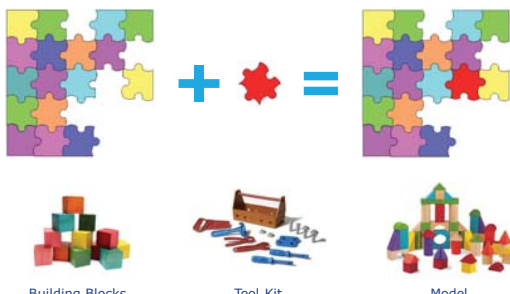


## Property Estimation Framework

- Property Estimators

Description	Estimator	Unit	Validity conditions
Default ambient temperature	25	°C	—
Wind speed	1.5	m/s	RMP Scenario – Worst-case
HD ratio from diameter	1	m/m	Shape = Spherical
Storage condition from roof type	Atmospheric	—	Roof Type = Floating Roof Roof Type = Internal Floating Roof Roof Type = Open Roof
Diameter from volume	Properties	m	Shape = Spherical
Energy magnitude from calculated seismic	Storage Condition: Atmospheric	—	—
Peak ground acceleration	Shape: Cylindrical Vertical	—	—
U.S. EPA RMP Liquid Factor Boiling	Roof Type: Floating Roof	kg	Region = Western USA
Duration of fireball	Construction Material: Steel	—	—
	Volumes: 22285 m <sup>3</sup> *	—	Fire/Explosion Event = BLEVE
	Height: 14.00 m*	—	—
	Diameter: 147.64 ft (45.00 m)	—	—
	HD Ratio: 0.3114 m/m*	—	—
	FBI Level: 85 %*	—	—
	L/D FRAP: 92.47*	—	—
	HD FRAP: 0.7324 m/m*	—	—


## Property Estimation Framework



Building Blocks + Tool Kit = Model


## Property Estimation Framework

- Minimizes data input
  - Estimates missing data
- Increases flexibility
  - Dynamic model building
- Provides extensibility
  - Custom properties
  - Custom estimators
- Selects most suitable
  - Recursive
  - Exhaustive



## Plants Module

- Plants
  - Industrial activity
  - Site properties
- Plant Units
  - Unit characteristics
  - Stored substances
- Typical Plant Units
- Substances
  - Identifiers
  - Physicochemical properties



## Hazards Module

- Natural Hazards
  - Hazard parameters
- Earthquake Catalog Data
  - Continuous monitoring
  - Automated update
- Hazard Maps
  - Shakemaps
- On-site Hazard Data
- Natechs
  - Damage parameters

**Natech Information**

Hazard: Istanbul Earthquake Turkey 100000017  
 Facility: Turkish Petroleum Refineries Corp. (TPRC) Izmit Refinery, Turkey

**On-site Hazard Parameters**

European Macroseismic: Continuous  
 Horizontal peak ground acceleration: 1.27 g  
 Vertical peak ground acceleration: 0.2 g  
 Peak Ground Displacement: 45-60 cm

**References**

1. Çapan, S. "The natech event during the August 17, 1999 Istanbul Earthquake aftermath and its..."
2. Doukaki, E., Eski, M. "Physical and economic losses sustained by the industry in the 1999 Izmit..."
3. Housner, G. J. and Gao, A. M. "Vulnerability and technological disaster analysis: lessons for..."
4. Ercan, F., Çapan, S. "Natech earthquake and TSPING for 2005..."
5. Rinaldi, M. "Report on damage to industrial facilities in the 1999 Istanbul earthquake, Turkey..."

**Natech Damages**

No. Process Unit Type: Process Unit Properties  
 Damage Type: Storage Tank, Storage Container, Atmospheric  
 Road Type: Floating Road  
 Construction Material: Steel  
 Base Support Type: Unreinforced

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## Assessment Module

- Damage Classifications
- Fragility Curves
- Risk States
  - Non-linear DS-RS relations
  - Damage parameters, e.g.:
    - Natech event (e.g. BLEVE)
    - Conditional probability (e.g. 50%)
    - Volume involved (e.g. 10 %v)
  - Validity conditions



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## Risk Assessment

**Create Risk Assessment**

Name: Near the Best Case of Results, Japan, 2002-12-18

**Risk Assessment Parameters**

1. Hazard: Hazard Severity: \*\* P value (2) \*\*  
 2. Hazard: Hazard: \*\* P value (2) \*\*  
 3. Hazard: Hazard: \*\* P value (2) \*\*  
 4. Hazard: Hazard: \*\* P value (2) \*\*

**Risk Assessment**

Damage Classification: D12  
 Conditional Probability: 0.001  
 Volume Involved: 10 %v

**Facilities**

1. Istanbul Refinery Plant, Turkey  
 2. Istanbul Refinery Plant, Turkey  
 3. Istanbul Refinery Plant, Turkey  
 4. Istanbul Refinery Plant, Turkey  
 5. Istanbul Refinery Plant, Turkey  
 6. Istanbul Refinery Plant, Turkey  
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 100. Istanbul Refinery Plant, Turkey

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## Status and Application

- Currently implemented for earthquakes and fixed installations and pipelines
- ~ 20,000 earthquakes (> M 5.5)
- ~ 10,000 shakemaps
- > 5,500 industrial facilities
  - Refineries
  - Power plants
- > 64,000 plant units
  - Storage tanks
- Complete implementation of U.S. EPA RMP Offsite Consequence Analysis methodology
- Application areas:**
  - Land-use planning
  - Emergency planning
  - Preliminary Natech damage estimation
  - Early warning

## Natural Hazard

- Istanbul Earthquake
- Scenario
  - JICA (2002) Model A
- Epicenter
  - 40° 45.00'N 29° 24.00'E
  - Focal depth 10 km
- Fault
  - Fault length 154 km
  - Strike-slip
- Magnitude
  - Mw 7.5



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## Industrial Plant

- Located in Izmit Bay
- Fiber production
- 315,000 ton/year capacity



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## Industrial Plant Units

Plant Unit	Code	Type	Substance	Properties
1.	PR-1	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
2.	PR-2	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
3.	PR-3	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
4.	PR-4	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
5.	PR-5	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
6.	PR-6	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
7.	PR-7	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
8.	PR-8	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
9.	PR-9	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
10.	PR-10	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
11.	PR-11	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
12.	PR-12	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
13.	PR-13	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
14.	PR-14	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
15.	PR-15	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
16.	PR-16	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
17.	PR-17	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
18.	PR-18	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
19.	PR-19	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar
20.	PR-20	Storage Tank	Acrylonitrile	Shape: Cylindrical vertical; d: 40.2 m; Roof Top Condition: Atmospheric; Pmax: 1.07 bar

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## Risk Assessment – Kerosene

Consequence: Pool fire		$d_e$	6.18 km
End-point: 2 <sup>nd</sup> degree burns (40s exp.)		PGA	0.7852 g
DS1 No release		PGV	167.92 cm/s
DS2 No release		MMI	10.07
DS3 1.24 m <sup>3</sup> release 248 m <sup>2</sup> pool (within dike) 69 m end-point distance		HAZUS, 2010	
DS4 619 m <sup>3</sup> release 415 m <sup>2</sup> pool (within dike) 90 m end-point distance		DS1	45.00%
DS5 1238 m <sup>3</sup> release 8588 m <sup>2</sup> pool (dike overflow) 408 m end-point distance		DS2	46.56%
		DS3	5.86%
		DS4	0.87%
		DS5	1.72%



## Risk Assessment – Acrylonitrile

Consequence: Atmospheric dispersion		$d_e$	6.25 km
End-point: ERPG-2 (0.076 mg/L)		PGA	0.7848 g
DS1 No release		PGV	167.83 cm/s
DS2 No release		MMI	10.06
DS3 62 m <sup>3</sup> release 1238 m <sup>2</sup> pool (within dike) 1.29 km end-point distance		HAZUS, 2010	
DS4 3100 m <sup>3</sup> release 2009 m <sup>2</sup> pool (within dike) 1.93 km end-point distance		DS1	0.90%
DS5 6200 m <sup>3</sup> release 8588 m <sup>2</sup> pool (dike overflow) 3.38 km end-point distance		DS2	13.19%
		DS3	28.34%
		DS4	18.33%
		DS5	39.25%



## Pipeline Natech Risk Assessment

- Prototype completed in 2016 (JRC Technical Report JRC101463)
- Pipeline-specific entities
  - Pipeline
  - Pipeline Segment
  - Point of interest (POI)
- Pipeline-specific data
  - Damage states
  - Fragility functions
  - Properties
  - Property estimators



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## Pipeline Natech Risk Assessment

- Pipeline-specific features
  - Overlapping segments
  - Auto-segmentation
  - Automated POI generation
  - Impact zone consolidation

Segment A.1	Segment A.2	Segment A.3	Point of Interest
Segment A.1	Segment A.2	Segment A.3	Point of Interest

Damage and Consequence Parameter	POI 1	POI 2
Damage probability, = RSD (inverted scale)	0.1 - 10 <sup>-1</sup>	0.1 - 10 <sup>-1</sup>
Damage probability, = RSD (significant loss)	0.1 - 10 <sup>-1</sup>	0.1 - 10 <sup>-1</sup>
Release rate	0.1 kg/s	0.1 kg/s
Population point diameter	11 m	11 m
Stop point distance (3 vehicle)	27 m	27 m

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## Flood Natech Risk Assessment

- 1<sup>st</sup> Phase of the prototype is completed (MAHB-ECHO AA 2015-2016)
- Collection of scientific and technical knowledge
  - Methodologies
  - Hazard data sources
  - Equipment vulnerability
  - Consequence analysis
- Gap analysis
  - Modifications
  - Further development



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## Flood Natech Risk Assessment

- EFAS/RAPID-N interoperability (JRC Technical Report JRC105055)
- Benefits
  - Flood hazard data for natech risk assessment
  - Natech risk data for emergency management
  - Flood forecasts → Natech Alert
  - Data sharing/cooperation between JRC systems



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## RAPID-N: Ongoing and future research

- Extension to other natural hazards and infrastructures
  - Pipelines (ongoing), Floods (ongoing), Lightning (planned)
- Automated Natech damage and consequence estimation (Alert)
  - Reporting to interested parties and authorities
- Cascading effects
- Consideration of risk receptors

Thank you  
for your attention!

<http://rapidn.jrc.ec.europa.eu>

Contact

[elisabeth.krausmann@ec.europa.eu](mailto:elisabeth.krausmann@ec.europa.eu)

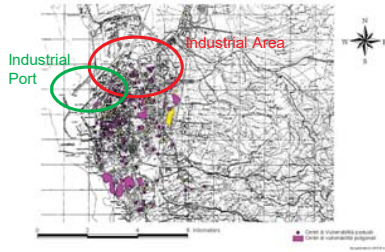
[serkan.girgin@ec.europa.eu](mailto:serkan.girgin@ec.europa.eu)





## Complexity of impact area

- Residential area and industrial facilities may have limited separation distances (if any) in specific contexts

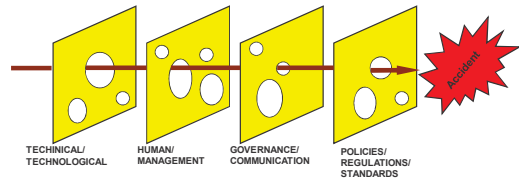


Natech Quantitative Assessment by ARIPAR tool  
V. Cozzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017

## Barriers

- Barriers may be present to cascading events
- Barriers may be affected as well by the natural event (common cause failure)
- The presence of barriers as well as their possible failure needs to be taken into account in quantitative assessment of Natech scenarios



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## Quantitative Assessment of Natech

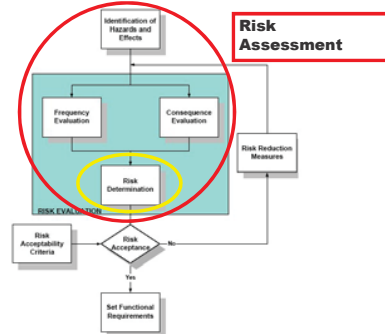
- Quantitative assessment of Natech scenarios deals with:
  - HILP events - falling outside common experience of analysts and responders
  - A high number of complex overall scenarios - simultaneous events, alternative final scenarios, escalation
  - Complex characterization of hazard
  - Complex description of impact area
  - Need to include non-perfect barriers in the analysis and early warning systems
- Quantitative Risk Assessment is usually applied to cope with a high number of scenarios having different credibility
- Geographical Information Systems (GIS) software is adopted to deal with the detailed characterization of complex areas

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V. Cozzani, University of Bologna, Italy

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## Risk Assessment and Management:

Even if QRA is a tool widely used in current practice, application to Natech is recent (2007) and still limited mostly to research

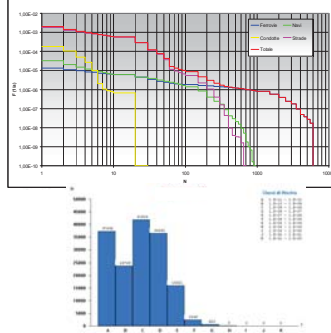


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## Detailed Risk Indexes

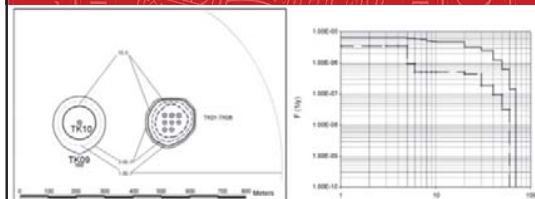
- local specific individual risk (LSIR)
- individual risk per annum (IRPA)
- Societal risk: F/N curves
- Societal risk: I-N histogram
- Societal risk: Potential Life Loss (PLL)
- Expectation value (EV)



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## QRA of Natech events



First complete QRA of a Natech event was published in 2007

G. Antonioni, G. Spadoni, V. Cozzani: A methodology for the quantitative risk assessment of major accidents triggered by seismic events. *J. Hazardous Materials* 147 (2007) 48-59

Early studies date back to 2003 and 2005:

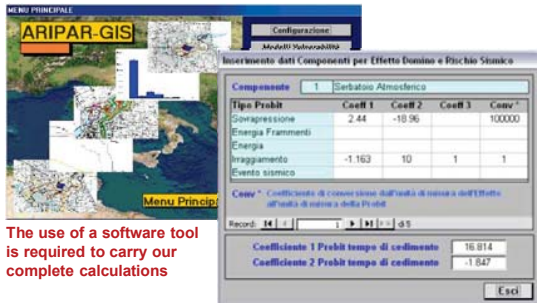
G. Fabbrocino, I. Iervolino, F. Orlando, E. Salzano: Quantitative risk analysis of oil storage facilities in seismic areas, *J. Hazard. Mater.* 123 (2005) 61-69

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## The ARIPAR-GIS software

First complete application of QRA to Natech was supported by the ARIPAR-GIS software



The use of a software tool is required to carry out complete calculations

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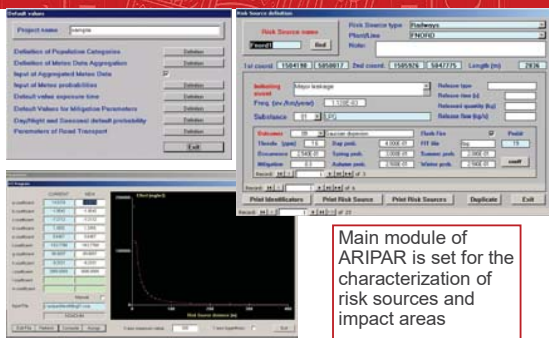
## The ARIPAR-GIS software

- ✓ In 1988 the ARIPAR project was launched (Analysis of Risks in the Industrial Area and Port of Ravenna - Italy)
- ✓ ARIPAR project is ambitious for the time: detailed characterization of industrial risk
- ✓ Several qualified public and private stakeholders participated: EC Joint Research Centre, University of Bologna, Civil Protection, Snamprogetti....
- ✓ 1990: ARIPAR software is launched
- ✓ 1996: first development of GIS interface
- ✓ 1996-2000: GIS interface continuously improved
- ✓ 2003: prototype for the assessment of domino effect
- ✓ 2005: prototype for the assessment of Natech events

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## The ARIPAR-GIS software

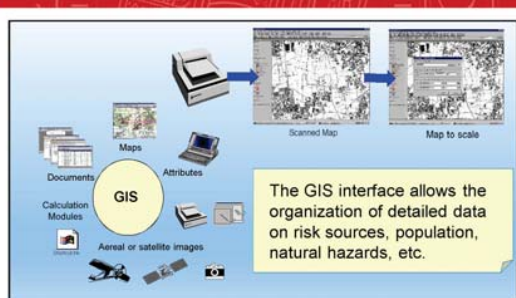


Main module of ARIPAR is set for the characterization of risk sources and impact areas

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## The ARIPAR-GIS software



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## The ARIPAR-GIS software

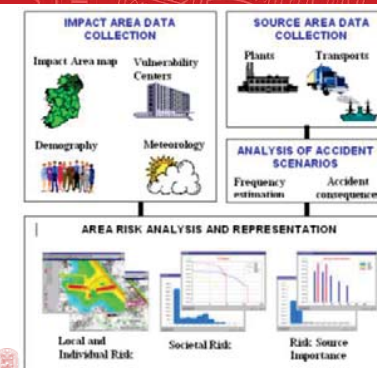
- ARIPAR-GIS was applied to the detailed analysis of several extended industrial areas in Italy

Data on the main Italian area risk analysis studies performed using the ARIPAR software									
area	plants	scenarios (fixed inst.)	road, rail transport	pipeline transport	ext. (km <sup>2</sup> )	study developed by	on behalf of		
Ravenna	47	379	yes	yes	205	Snamprogetti-ENEL-ENI and University of Bologna	Civil Protection Department - Emilia Romagna Region		
Livorno	35	306	yes	yes	45	Snamprogetti	Local control authorities (ARIPAT, Regione Toscana)		
Pesaro	5	46	yes	no	3	University of Pisa	Local control authorities (ARIPAT, Regione Toscana)		
Marina	-	-	yes	no	25	University of Pisa	Local control authorities (Provincia di Livorno, ISS, Rete Ferroviaria Italiana SpA)		
Terra	-	-	yes	no	10	University of Bologna			
Prato	210	to be defined	yes	yes	>100	Snamprogetti	Ministry of the Environment		
Milazzo	43	191	yes	yes	20	University of Messina	Local industry committee		
Gela	6	27	yes	yes	30	University of Messina			

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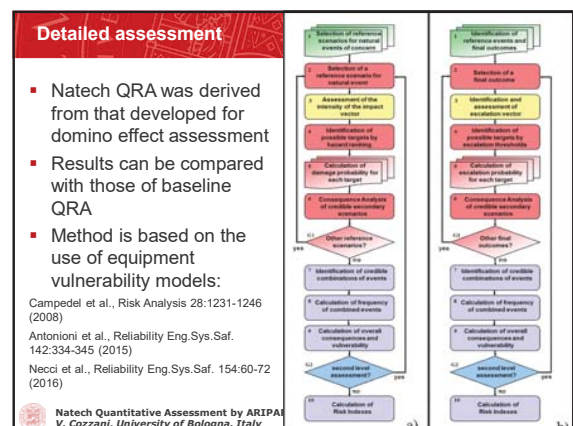
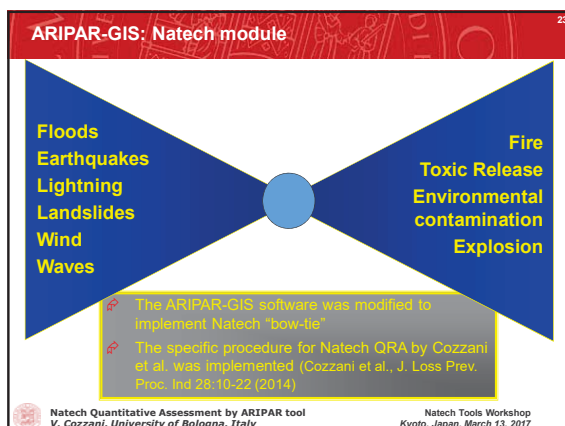
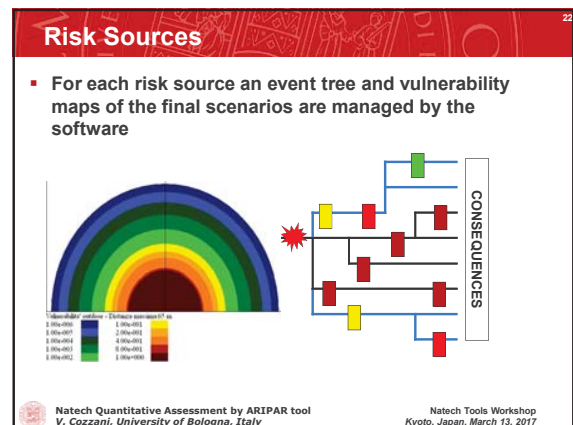
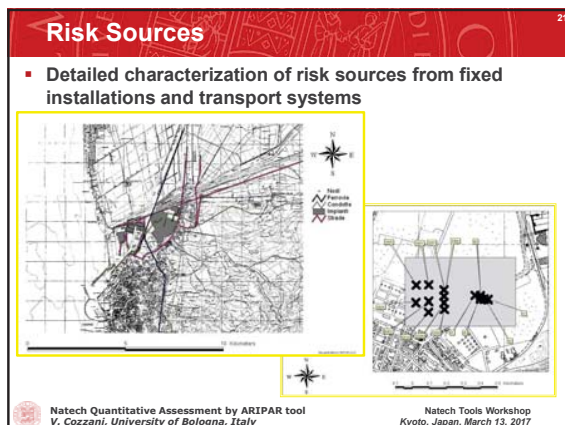
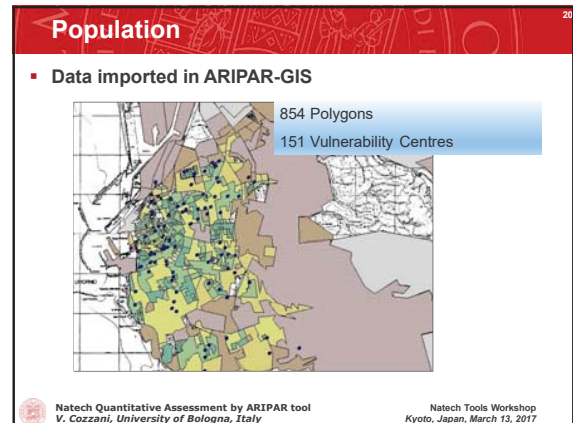
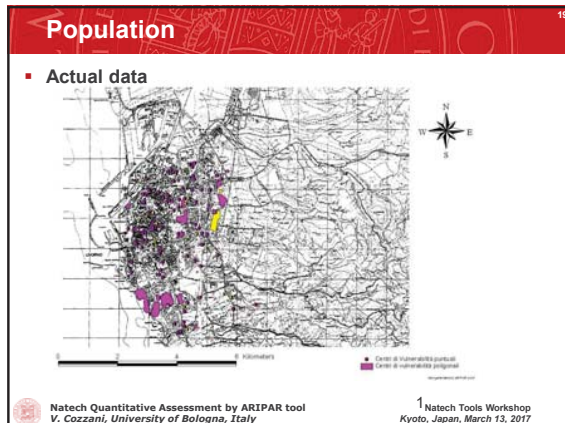
## The ARIPAR-GIS software



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## 25

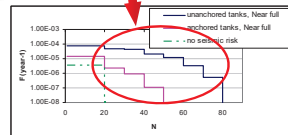
A reference layout for a tank farm of an oil refinery was considered

Reference scenarios were selected for both conventional events and LOCs induced by earthquakes

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## 26

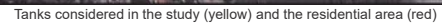
Strong increase in societal risk  
(in particular for high N values)



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## 29



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## 30

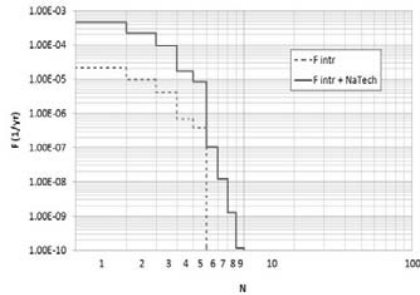
Map generated by ARIPAR 4.0

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## Societal risk

Societal Risk: F-N curves



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## Case Study 3: Italy, Flood

### Pressurized and atmospheric tank farm



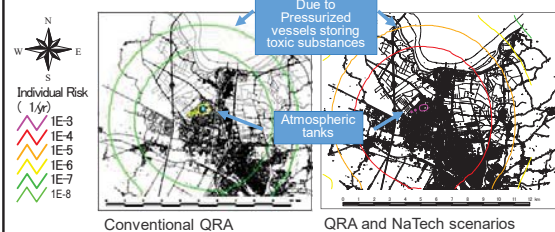
Vessel features	Pressurized vessels					Atmospheric vessels		
	P1 to P9	P10 to P16	P17	P18 to P20	P21 to P23	S1	T1-T4	T5-T8
Nominal capacity (m³)	50	30	115	150	100	3179	6511	6511
Substance contained	Propylene	Propane	LPG	Ammonia	Chlorine	Organic solvent	Gasoline	Benzene
Physical state	Liquefied gas	Liquefied gas	Liquefied gas	Liquefied gas	Liquefied gas	Liquid	Liquid	Liquid
Inventory (metric ton)	32	12	59	84	140	1550	3656	4275

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## Individual Risk

- LSIR profile increases up to three order of magnitude with respect to the QRA with conventional scenarios
- Frequency increment due to high severity of selected flooding

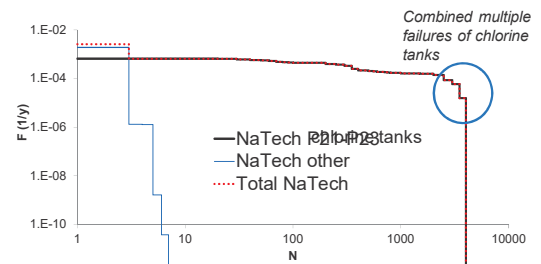


Natech Quantitative Assessment by ARIPAR tool  
V. Cazzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017

## Societal Risk: F-N Curve

- Pressurized vessels have a higher impact on the overall risk: relevant severity of toxic releases



Natech Quantitative Assessment by ARIPAR tool  
V. Cazzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017

## Conclusions /1

- ARIPAR-GIS software proved to be a robust tool to support Natech QRA
- Results obtained by the approach from different applications in Europe seem coherent
- The results provide a detailed quantification of Natech risk even for complex impact areas and complex scenarios
- Quantitative assessment of Natech risk supports decision making and captures the effect of safety barriers

Natech Quantitative Assessment by ARIPAR tool  
V. Cazzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017

## Conclusions /2

- ARIPAR-GIS addresses detailed risk assessment: it is not a screening tool
- QRA requires expert users and a deep knowledge of models, in particular when addressing consequence analysis
- Uncertainty needs to be managed when detailed approaches are developed
- Risk results are highly dependent on natural hazard characterization
- Equipment vulnerability model are the key element required for the implementation of the approach

Natech Quantitative Assessment by ARIPAR tool  
V. Cazzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017

## Acknowledgements



- ✓ All members of LISES - Laboratory of Industrial Safety and Environmental Sustainability at DICAM - UniBO: *Giacomo Antonioni, Sarah Bonvicini, Gigliola Spadoni, Alessandro Tugnoli*
- ✓ Gabriele Landucci, Università di Pisa, Italy
- ✓ Amos Necci, currently at EC JRC, Ispra site, Italy

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Natech Quantitative Assessment by ARIPAR tool  
V. Cozzani, University of Bologna, Italy

Natech Tools Workshop  
Kyoto, Japan, March 13, 2017






WORKSHOP OF TOOLS FOR NATECH RISK MANAGEMENT  
 Uji Campus, Kyoto University  
 MARCH 13TH, KYOTO

## QUANTITATIVE ASSESSMENT OF EARTHQUAKE AND TSUNAMI NATECH SCENARIOS

A CASE STUDY OF A REFINERY IN ITALY

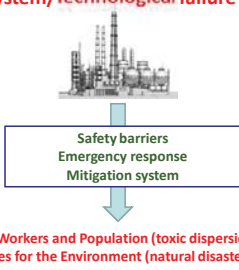
ERNESTO SALZANO  
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## Technological risks

### System/Technological failure



Consequences for Workers and Population (toxic dispersion, fire, explosion)  
 Consequences for the Environment (natural disaster, pollution)

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## Technological risks



Deepwater Horizon: after burning for 36 hours the rig sank on April 22, 2010

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## Technological risks

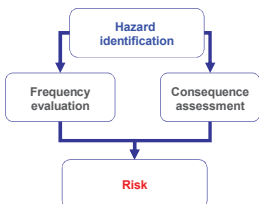


- The pipe that channelled oil 1,400 metres up from the sea floor spewed out in 5 million barrels of oil (twice as big as the largest oil spill event ever) in 3 months
- A continuous plume of oil, more than 35 kilometers in length


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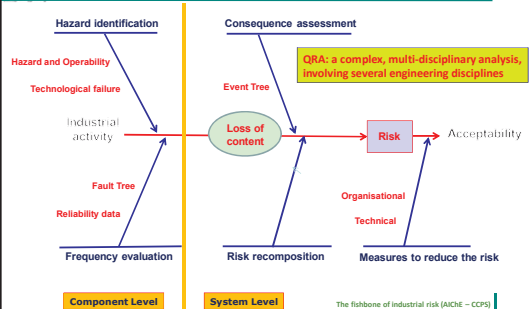
## Quantitative Risk Assessment



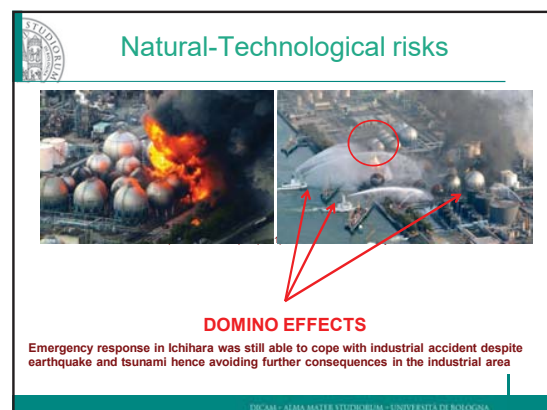
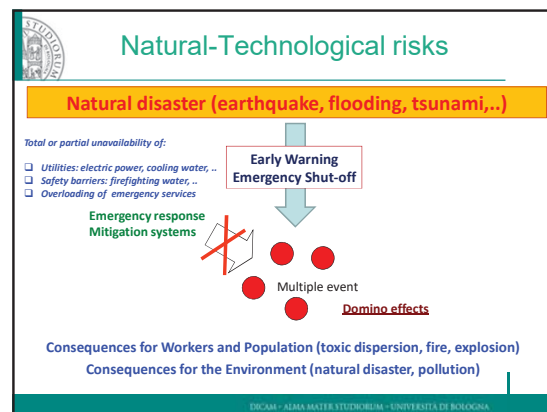
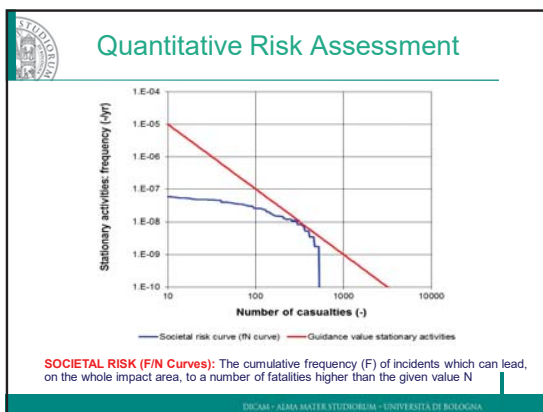
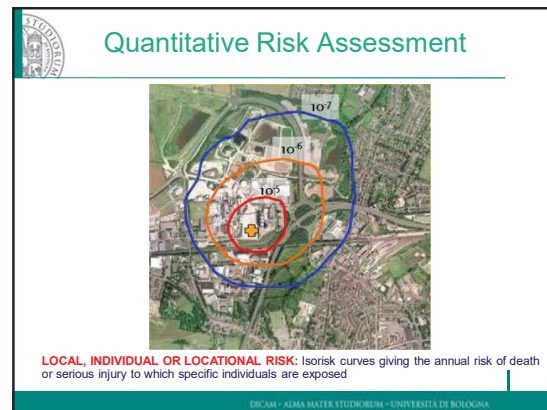
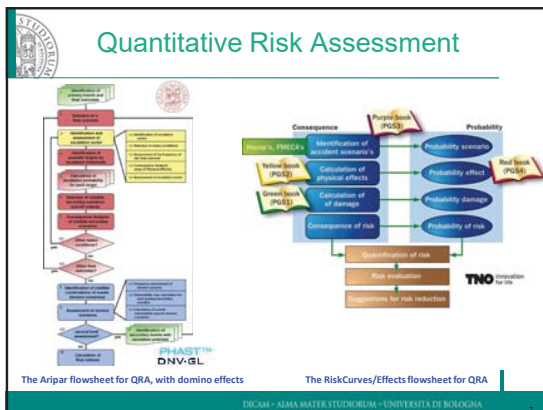
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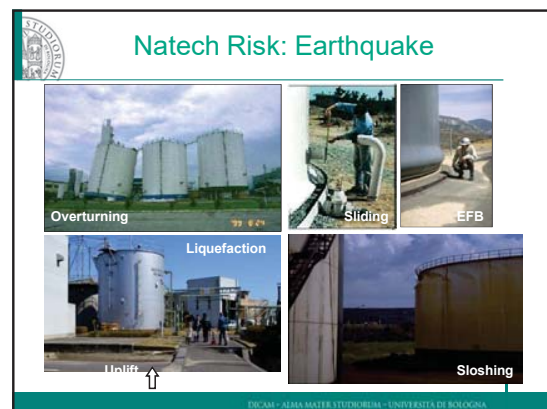
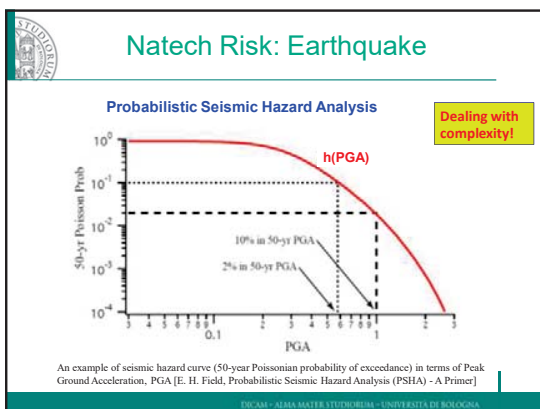
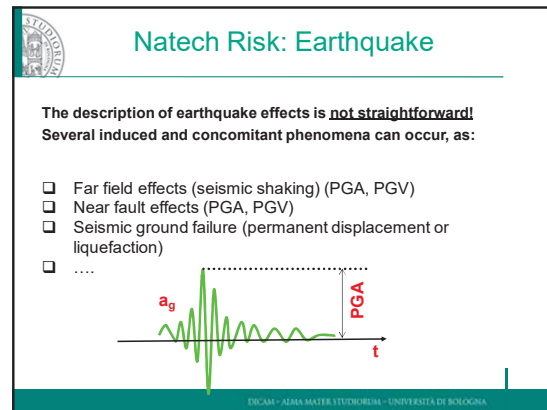
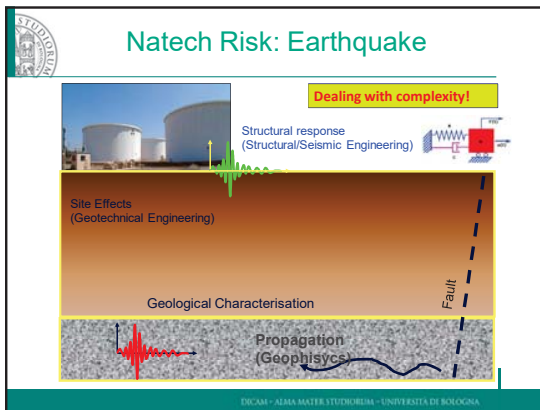
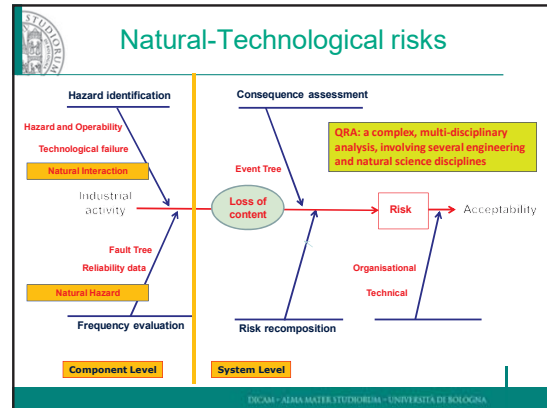
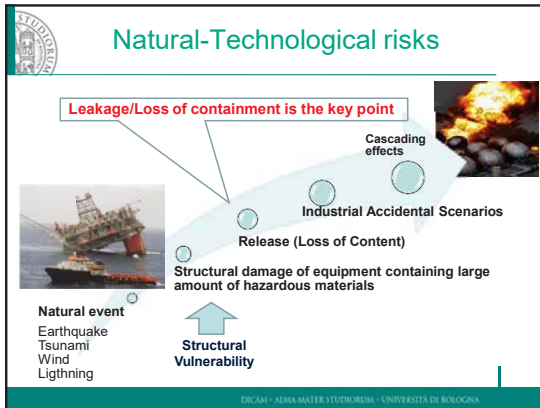
## Quantitative Risk Assessment



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## Natech Risk: Earthquake

Worldwide  
Standardized  
Design and  
Fabrication



Dealing with  
complexity!



Availability of  
Post Damage data

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## Natech Risk: Earthquake

**Damage State (DS): Performance levels based on structural damage**

- DS1 - absence of structural damage
- DS2 - slight damages to structures
- DS3 - moderate structural damages
- DS4 - Extensive damage to structures
- DS5 - total collapse of structure

**Main scope:**

- Return-to-Service
- Evaluation of post-event economical losses
- Reconstruction
- Repair
- Upgrading


Dealing with  
complexity!

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## Natech Risk: Earthquake

**Structural Vulnerability**

For each Damage State (DS) for a specific structure, a structural vulnerability (**fragility function**) in terms of the standard normal cumulative distribution function for the Intensity Measure (IM) of earthquake can be defined as:

$$P[DS_i | IM] = \Phi \left[ \frac{\ln(IM) - \ln(\bar{IM})}{\beta} \right]$$


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## Natech Risk: Earthquake

**For QRA, Performance levels based on Loss of Content are needed**

**Risk State (RS)**

- RS3 (Minor risk): release from a 10 mm equivalent diameter
- RS2 (Severe risk): complete release of inventory in 10 min
- RS1 (Instant risk): instantaneous release of entire inventory

**For each Risk State (RS) and for any specific equipment containing hazardous materials, a fragility function can be defined in terms of limit state probability as:**

$$P[RS \geq RS_i | IM] = \Phi \left[ \frac{\ln(IM) - \mu}{\beta} \right]$$

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## Natech Risk: Earthquake

**Equipment Fragility based on PGA**

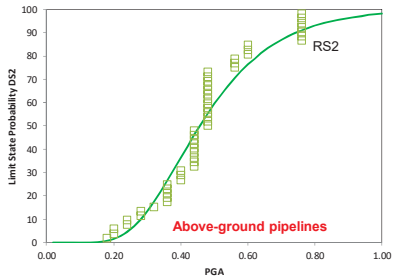
- ☐ Atmospheric tanks
- ☐ Pipelines
- ☐ Atmospheric equipment
- ☐ Pressurized tanks
- ☐ Pressurized equipment
- ☐ Reactors

$$P[RS \geq RS_i | PGA] = \Phi \left[ \frac{\ln(PGA) - \mu}{\beta} \right]$$


N	RS	DS	Tank	FL	Fragility $\mu$	Fragility $\beta$
1	≥ 2	≥ 2	Anchored	Near Full	0.300	0.600
2	3	≥ 4	Anchored	Near Full	1.250	0.650
3	≥ 2	≥ 2	Anchored	≥ 50%	0.710	0.800
4	3	≥ 4	Anchored	≥ 50%	3.720	0.800
5	≥ 2	≥ 2	Unanchored	Near Full	0.150	0.700
6	3	≥ 4	Unanchored	Near Full	0.680	0.750
7	≥ 2	≥ 2	Unanchored	≥ 50%	0.150	0.120
8	3	≥ 4	Unanchored	≥ 50%	1.060	0.800

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## Natech Risk: Earthquake



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## Natech Risk: Earthquake

Given a specific equipment, for each Risk State, the annual cumulative probability of Loss of Content (RS), is given by the combination of the vulnerability function and the Seismic Hazard function  $h(IM)$

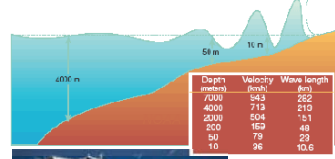
$$P[RS \geq RS_i | IM] = \int_{IM} P[RS \geq RS_i | IM] \cdot h(IM) dIM$$

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## Natech Risk: Tsunami


Tsunami characterisation: Water wave (velocity, inundation depth) and debris



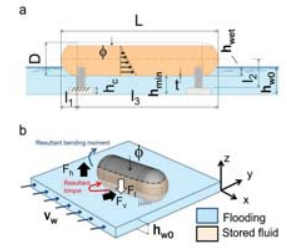
Depth (meters)	Velocity (km/h)	Wave length (km)
7000	943	282
4000	713	210
2000	504	151
1000	357	106
500	250	76
100	100	30



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## Natech Risk: Tsunami

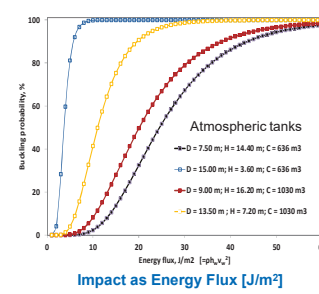


Analogy with flooding: damage probability as function of total pressure, thus a function of water **velocity** and water **height**

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## Natech Risk: Tsunami




Atmospheric tanks

- $D = 7.50$  m;  $H = 14.40$  m;  $C = 636$  m<sup>3</sup>
- $D = 15.00$  m;  $H = 3.60$  m;  $C = 636$  m<sup>3</sup>
- $D = 9.00$  m;  $H = 16.20$  m;  $C = 1030$  m<sup>3</sup>
- $D = 13.50$  m;  $H = 7.20$  m;  $C = 1030$  m<sup>3</sup>

Impact as Energy Flux [J/m<sup>2</sup>]

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## Natech Risk: Tsunami

Depth of penetration  $\tau$  by small and large fragment

DAMAGE RELEASE:  $\tau > \theta$  (shell thickness)


$$\zeta_{small} = k_s m_p^a u_o^b$$

$$\zeta_{large} = k_l \frac{m_p}{A_p} \log_{10} (1 + 5 \cdot 10^{-5} u_o^2)$$


$m_p$  = mass and area of fragment  
 $u_o$  = velocity of fragment

Target material	$k_s$	$k_l$	a	b
Concrete	1.8-10-5	1.0-10-3	0.4	1.5
Brickwork	2.3-10-5	2.5-10-3	0.4	1.5
Steel	6.0-10-5	5.0-10-5	0.3	1.0

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## Natech Risk: Tsunami



Steel Keel Weight  $\approx 100$  kg  
Surface  $= 2$  m<sup>2</sup>

Tsunami Wave Velocity  $= 5$  m/s  
Depth  $= 3$  m

$\zeta_{large} = 8$  mm  $\approx$  thickness of low section of atm tanks

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## Natech Risk: Tsunami

Tsunami Wave damages by Johnson number

$$J = \frac{u_o^2 m_p}{\sigma_D \theta r_p^2}$$

$$J = \frac{\rho V_o^2}{\sigma_D} \left( \frac{L}{\theta} \right)^n \left( 1 + \ln \frac{L}{L_p} \right)$$

m = mass of fragment  
r = fragment characteristic dimension  
u = velocity of fragment at the impact  
 $\theta$  = target wall thickness  
 $\sigma$  = dynamic yield stress of target  
L = characteristic length of target (p = partial)

Johnson	Regime
$10^{-1}$	Quasi-static elastic
$10^{-1}$	Moderate plastic behaviour
$10^{-1}$	Extensive plastic deformation
$10^{-1}$	Hypervelocity impact

STRESS meeting - Thessaloniki (GR) October, 12-14 2015

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31



## QRA Study for a refinery in Italy



Joint venture between Q8/ENI  
Capacity: 8.0 million tons/y

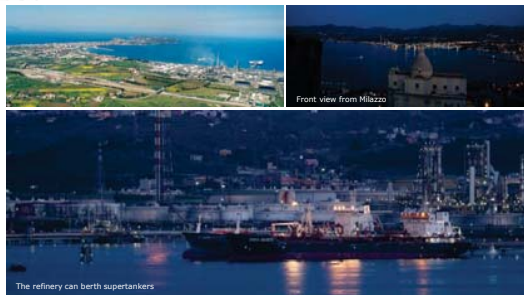
STREST

Milazzo Refinery, Sicily (Italy)

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## QRA Study for a refinery in Italy



The refinery can berth supertankers

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## QRA Study for a refinery in Italy



Flammable Gas and Liquid connection (pipework, loading arm) from the main site (storage, production) to berth

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## QRA Study for a refinery in Italy



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## QRA Study for a refinery in Italy

AREA I




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### QRA Study for a refinery in Italy

#### AREA II: Refining Units

1. Atmospheric Distillation
2. Vacuum Distillation
3. FCC (Fluid catalytic cracking)
4. Hydrocracking unit
5. LC Fining Residual Hydrocracker
6. Alkylation
7. Diesel Desulphurisation
8. Sulphur Recovery



Pressurised equipment, small scale  
(in terms of hazmat), safety  
instrumented systems for rapid  
shut-off


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### QRA Study for a refinery in Italy

#### AREA III: Storage Units

170 floating roof tank: 4 million m<sup>3</sup>


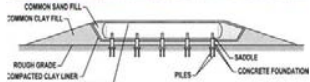
TANK PRODUCT	DIAM.	HEIGHT	CAPACITY (m <sup>3</sup> )
CRUDE	97	22	160,000
GASOIL	82.2	19	100,000
FUEL OIL	61	17	50,000
GASOLINE	61	17	50,000
NAPHTHA	24	15	7,000



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### QRA Study for a refinery in Italy

#### Area IV: Mounded Storage Unit

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### QRA Study for a refinery in Italy



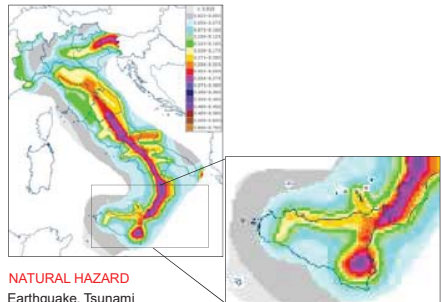
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### QRA Study for a refinery in Italy



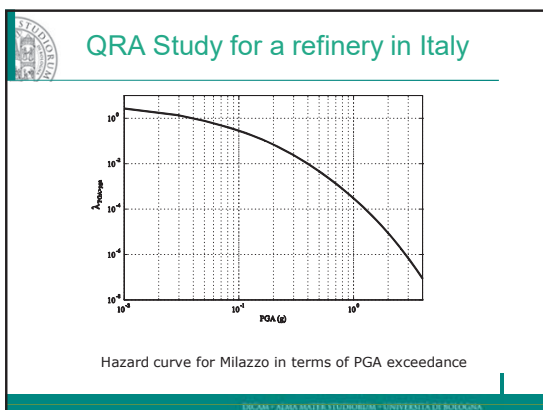
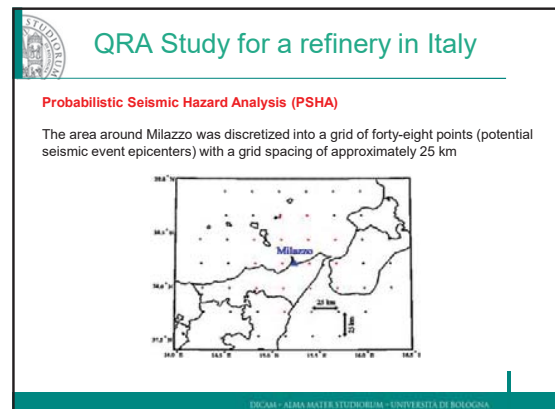
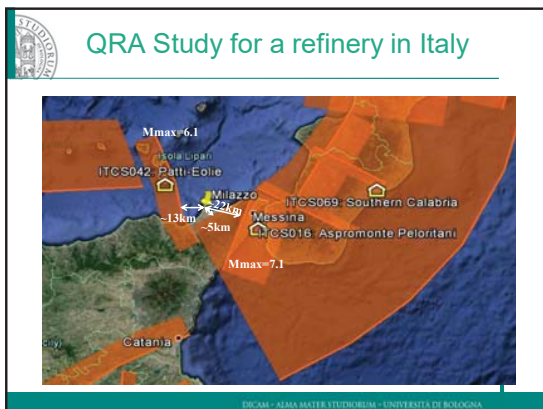
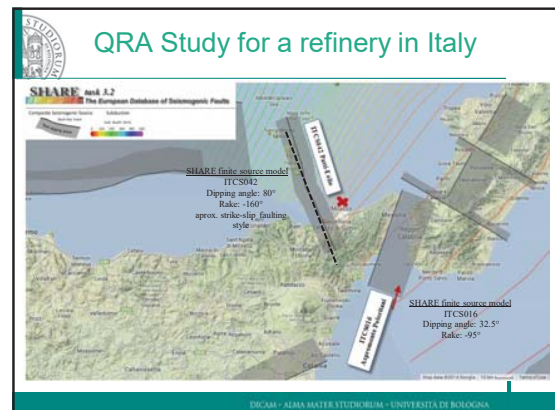
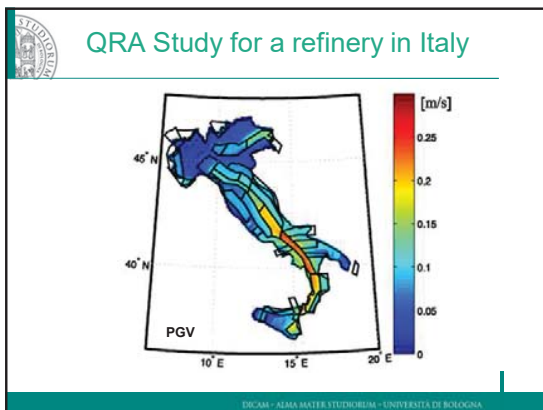
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### QRA Study for a refinery in Italy



NATURAL HAZARD  
Earthquake, Tsunami

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### QRA Study for a refinery in Italy

The **1908 Messina earthquake and tsunami** took about **123,000 lives**, in Sicily and Calabria, southern Italy.  
**...The gazometer was destroyed, with a dramatic fire fed by furious wind...**  
 [CdS 29/12/1908]

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### QRA Study for a refinery in Italy

Tsunami in Sicily (Stromboli) in 2002, 30th Dec

**At 13:55**, two petrol ships berthed in Milazzo moved laterally (slipped) for 10m, broke their moorings (4 wires) even disconnecting the loading arm, and eventually releasing diesel oil into the sea

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### QRA Study for a refinery in Italy

**Probabilistic Tsunami Hazard Analysis (PSHA)**  
 Numerical analysis of tsunami hazard in the area of Milazzo

Italian National Institute of Geophysics and Volcanology

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### QRA Study for a refinery in Italy

A) Maximum wave height distribution originated from the crustal event indicated with the red star (M=8.0);  
 B) Time history of the corresponding wave height for one randomly selected receiver

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### QRA Study for a refinery in Italy

**MEAN HAZARD MAP, 10<sup>4</sup> YR MRP**  
 $Pr(q > z, 1 \text{ yr}) = 10^{-4}$

FlowDepth [m]

Maximum flow depth distribution originated from the crustal event indicated with the red star (M=8.0)

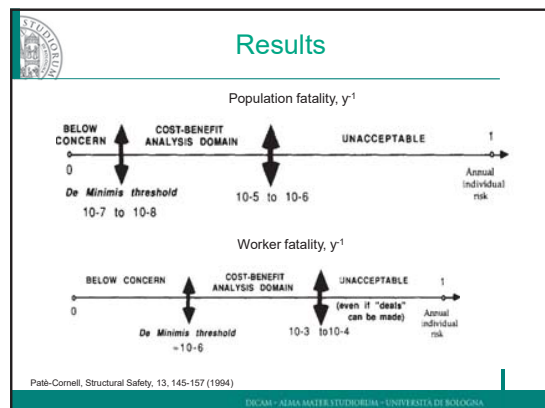
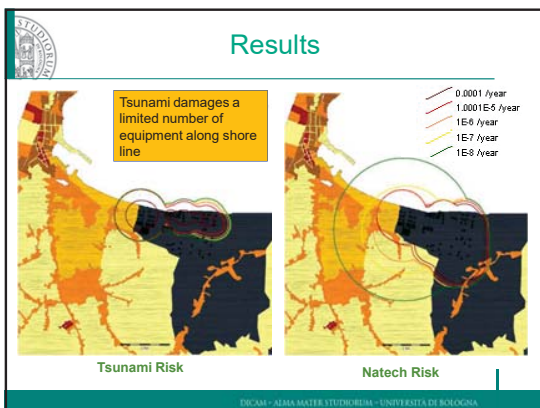
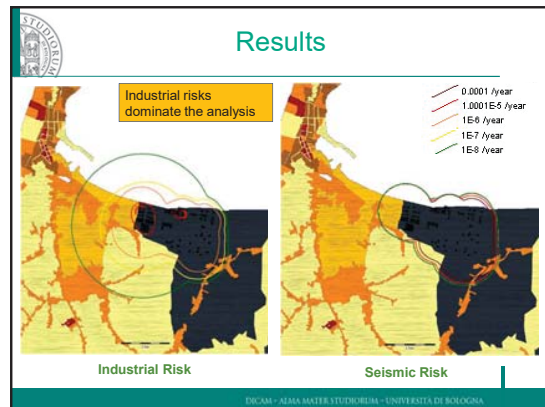
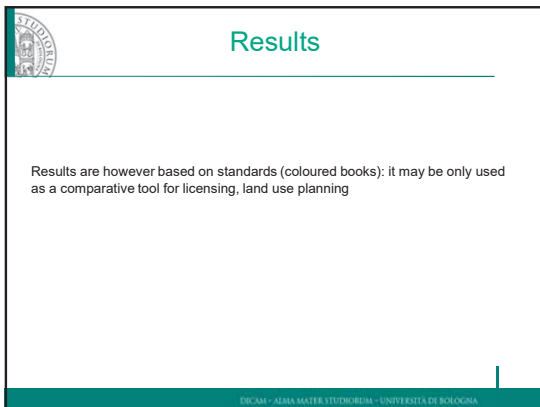
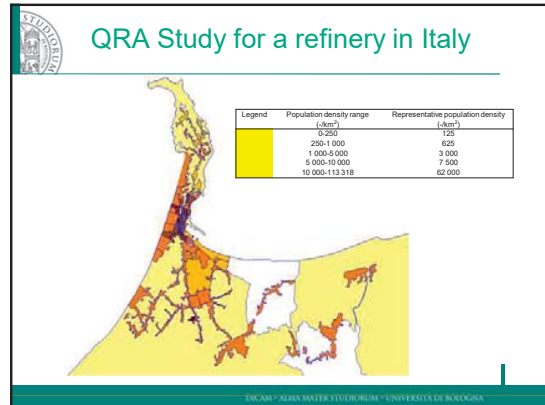
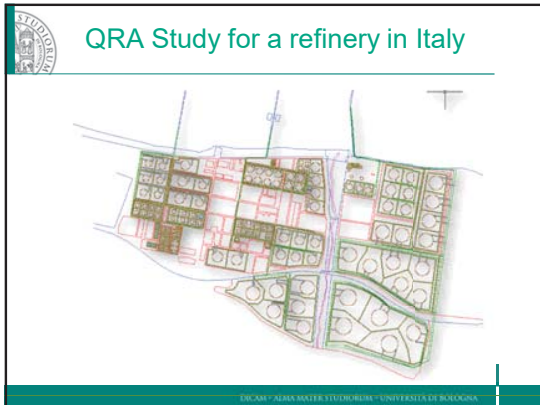
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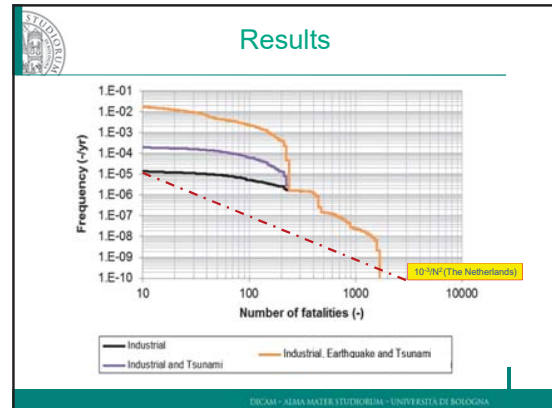
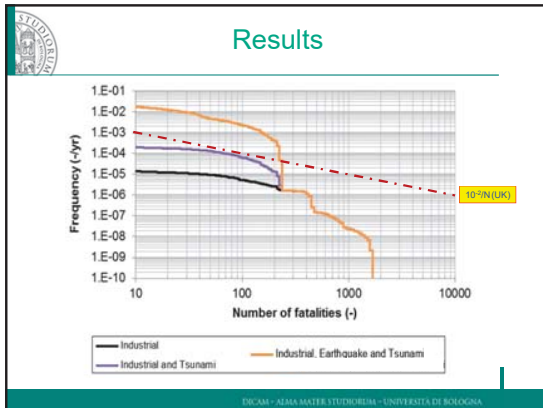
### QRA Study for a refinery in Italy

Item	Material	Unit	Value	Unit	Value
1	Gasoline	m³	1000	kg	7000
2	Gasoline	m³	1000	kg	7000
3	Gasoline	m³	1000	kg	7000
4	Gasoline	m³	1000	kg	7000
5	Gasoline	m³	1000	kg	7000
6	Gasoline	m³	1000	kg	7000
7	Gasoline	m³	1000	kg	7000
8	Gasoline	m³	1000	kg	7000
9	Gasoline	m³	1000	kg	7000
10	Gasoline	m³	1000	kg	7000
11	Gasoline	m³	1000	kg	7000
12	Gasoline	m³	1000	kg	7000
13	Gasoline	m³	1000	kg	7000
14	Gasoline	m³	1000	kg	7000
15	Gasoline	m³	1000	kg	7000
16	Gasoline	m³	1000	kg	7000
17	Gasoline	m³	1000	kg	7000
18	Gasoline	m³	1000	kg	7000
19	Gasoline	m³	1000	kg	7000
20	Gasoline	m³	1000	kg	7000
21	Gasoline	m³	1000	kg	7000
22	Gasoline	m³	1000	kg	7000
23	Gasoline	m³	1000	kg	7000
24	Gasoline	m³	1000	kg	7000
25	Gasoline	m³	1000	kg	7000
26	Gasoline	m³	1000	kg	7000
27	Gasoline	m³	1000	kg	7000
28	Gasoline	m³	1000	kg	7000
29	Gasoline	m³	1000	kg	7000
30	Gasoline	m³	1000	kg	7000
31	Gasoline	m³	1000	kg	7000
32	Gasoline	m³	1000	kg	7000
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51	Gasoline	m³	1000	kg	7000
52	Gasoline	m³	1000	kg	7000
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94	Gasoline	m³	1000	kg	7000
95	Gasoline	m³	1000	kg	7000
96	Gasoline	m³	1000	kg	7000
97	Gasoline	m³	1000	kg	7000
98	Gasoline	m³	1000	kg	7000
99	Gasoline	m³	1000	kg	7000
100	Gasoline	m³	1000	kg	7000

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- ### Conclusions
- ❑ Existing NaTech guidelines and standards concern the Return-to-Service or Serviceability Limit States (as in Hazus)
  - ❑ New vulnerability functions are needed, Loss of Content being the dependent variable
  - ❑ Natech risks may weight even more than industrial-related risks, particularly for oil&gas and chemical industry
  - ❑ Detailed Natech analysis needs multi-disciplinary expertise
  - ❑ Acceptability criteria are the nub of the problem for industrial and NaTech risks
  - ❑ For some natural disasters, early warning may be essential: emergency plan can be operating well before the occurrence of the event
- DISAM - ALMA MATER STUDIORUM - UNIVERSITÀ DI BOLOGNA

### Conclusions

Thank you for your attention!

ernesto.salzano@unibo.it

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## Oil and gas releases during large earthquakes and tsunami

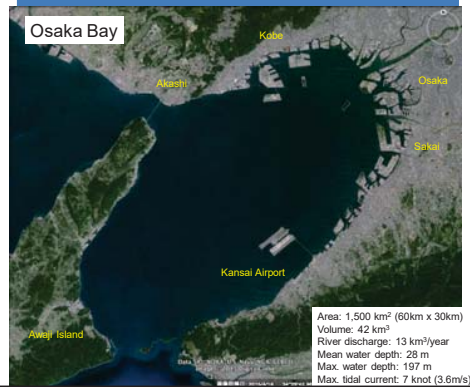
- A research initiative of Osaka University for disaster prevention in petrochemical complex -



Shin-ichi AOKI & Naomi KATO, Osaka University

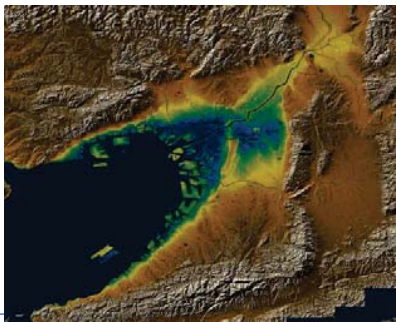
1

## Osaka Bay



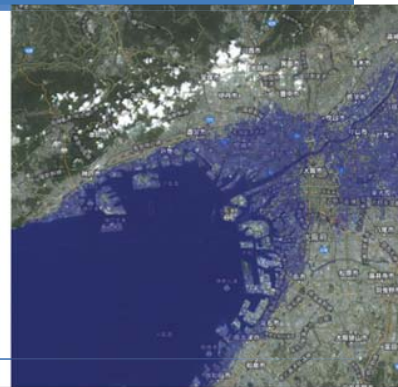
2

## Topography around Osaka Bay



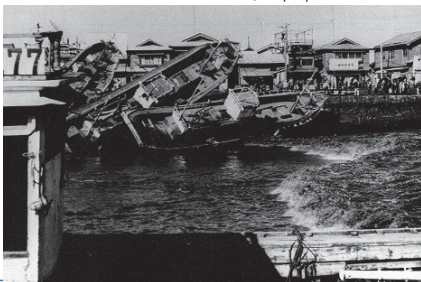
3

Inundation area in Osaka due to 5m sea level rise (w/o sea walls)



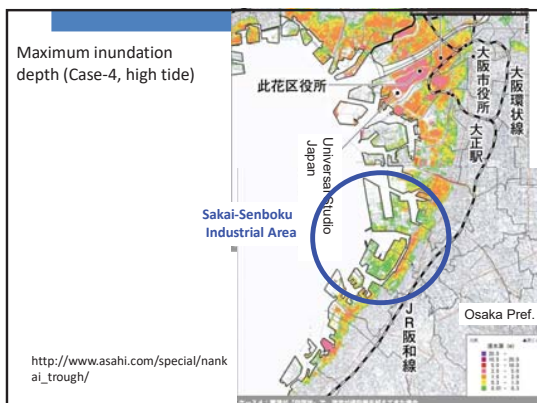
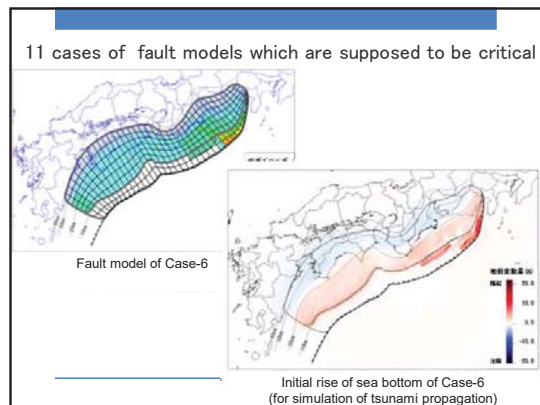
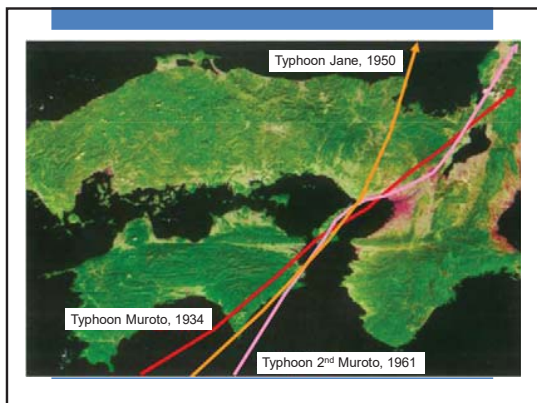
## Chilean Tsunami (1960)

Tsunami came one day after the earthquake in Chili.  
 Because of lack of information of tsunami, 100 people died.

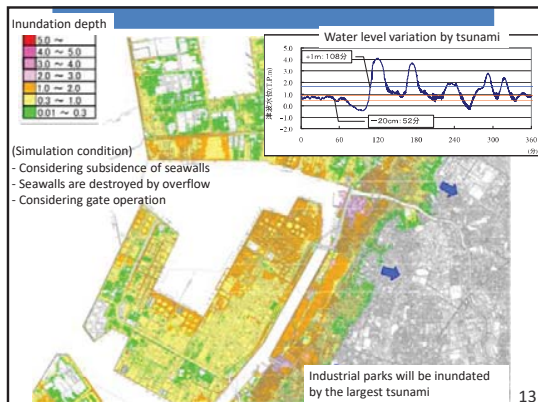


## Historical Disasters by Storm Surge

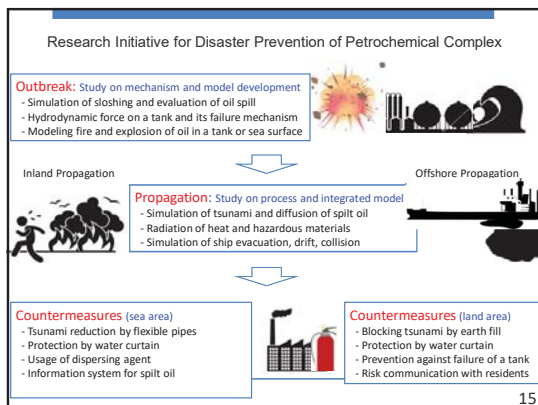
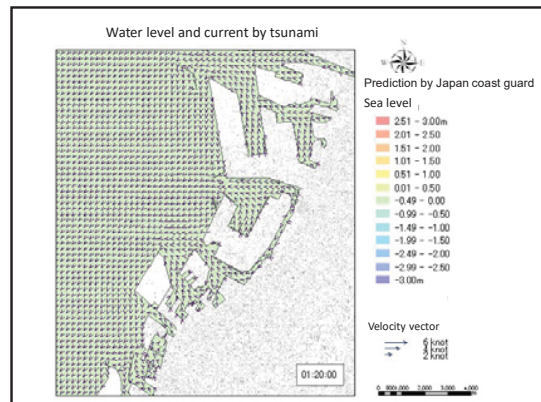
Year	Name	Location	People lost	Departure (cm)
1934. 9	Muroto	Osaka	3, 036	310
1945. 9	Makurazaki	Kyushu	3, 122	160
1950. 9	Jane	Osaka	534	270
1953. 9	No. 13	Ise	393	240
1959. 9	Isewan	Ise	5, 098	345
1961. 9	2 <sup>nd</sup> Muroto	Osaka	200	241
1970. 8	No. 10	Kochi	13	235
1991. 8	No. 19	Suo-Nada	4	310
1999. 9	No. 18	Ariake	16	180
2004. 8	No. 16	Seto	45	134 (Kobe)
10	No. 23	Kochi	3	253 (Kochi)







13

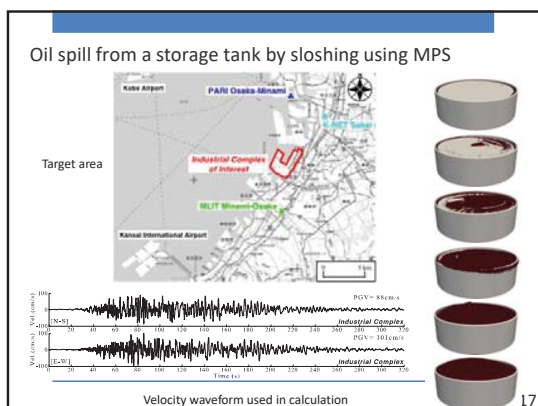


15

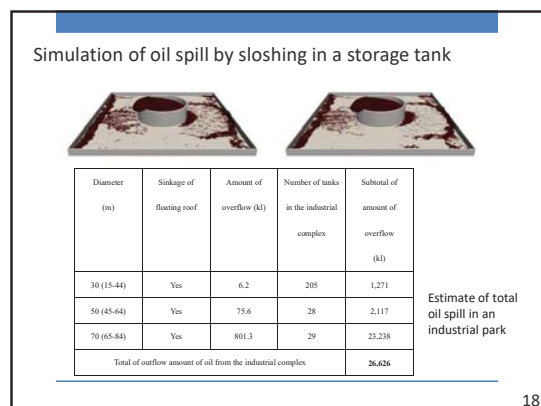
## Method of Research

- Numerical simulation using some mathematical models and CFD  
→ validation of the model
- Laboratory experiments for scaled models  
→ similarity, scale effect

16

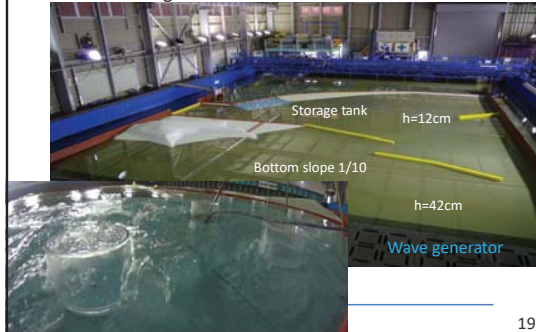


17



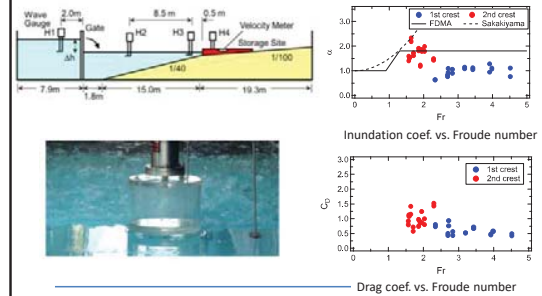
18

# Laboratory experiments on hydrodynamic forces by tsunami entering a harbor



19

# 2D Experiments on a tsunami wave force acting on a tank



20

# Numerical simulation of tsunami propagation and dispersion of spilt oil

## Sakai-Senboku Area

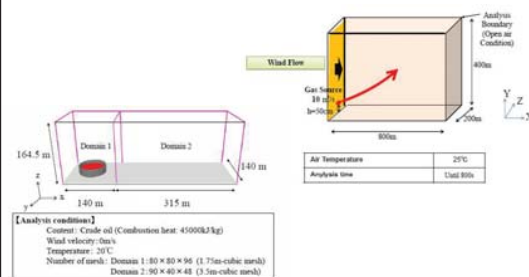


# Numerical simulation of tsunami propagation and dispersion of spilt oil

## Osaka Port

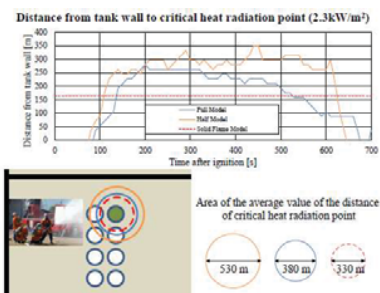


# Numerical simulation of heat radiation and gas diffusion from a tank



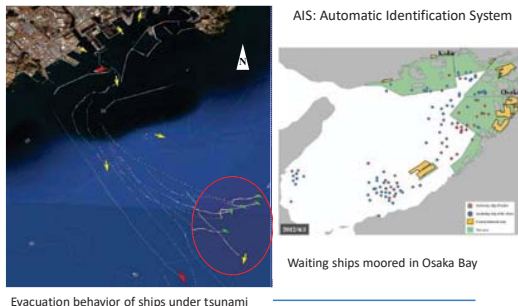
23

# Numerical simulation of heat radiation and gas diffusion from a tank



24

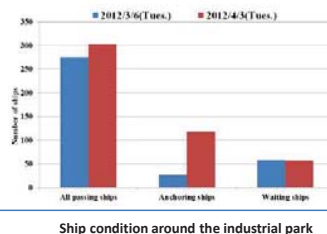
### Analysis of ship behavior by AIS data



25

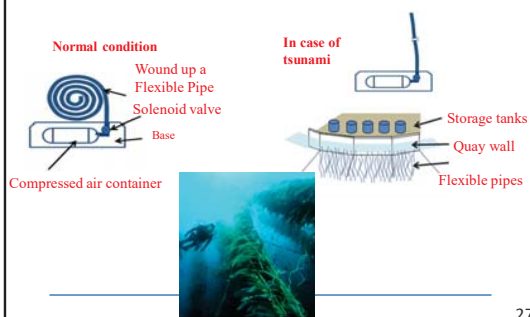
### Analysis of ship behavior by AIS data

Target area: Osaka Bay  
Date of investigation:  
03/06/2012: no wind  
04/03/2012: wind speed > 20m/s



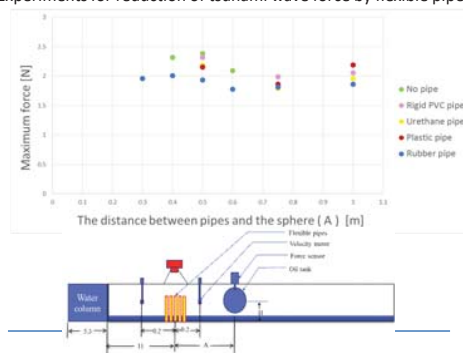
26

### Reduction of tsunami energy by flexible pipes



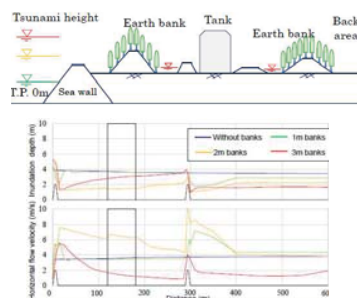
27

### Experiments for reduction of tsunami wave force by flexible pipes



28

### Blocking tsunami by an earth bank



29

### Outreach activities

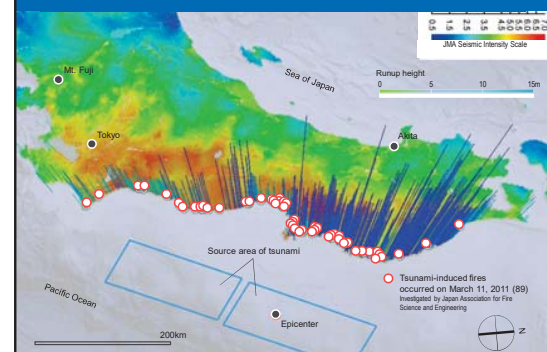
Exchange of opinions with residents near the industrial park



## Development of simulation tool for fire spread on floating oil in tsunamis

Tomoaki NISHINO (Building Research Institute)

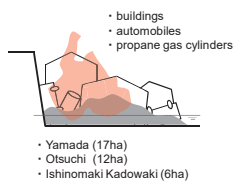
## Tsunami-induced fires in the 2011 Earthquake



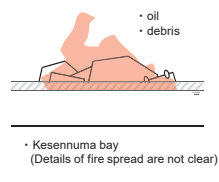
## Tsunami-induced fires in the 2011 Earthquake

- 89 ignitions occurred in tsunami inundation areas on March 11.
- Some of fires developed to large outdoor fires spreading 67ha.

### [A] Land type (accumulating combustibles)



### [B] Marine type (floating combustibles)



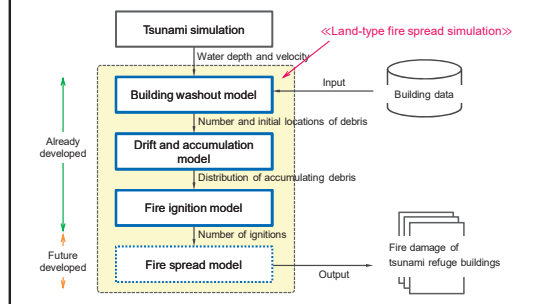
## Problems

- Some fires spread to tsunami refuge buildings and high grounds.
- Measures against tsunami-induced fires are not sufficient.
- There is no method for predicting tsunami-induced fires.

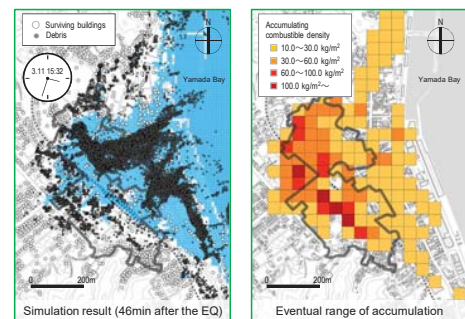


## Previous development

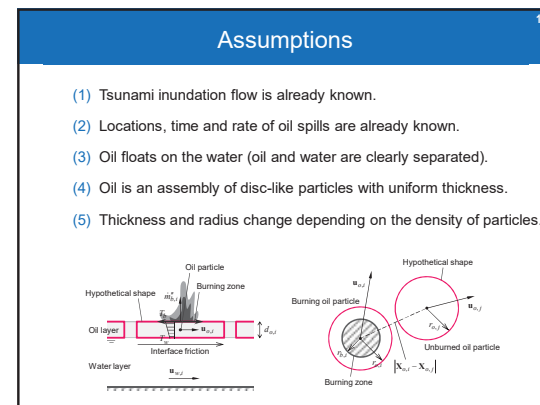
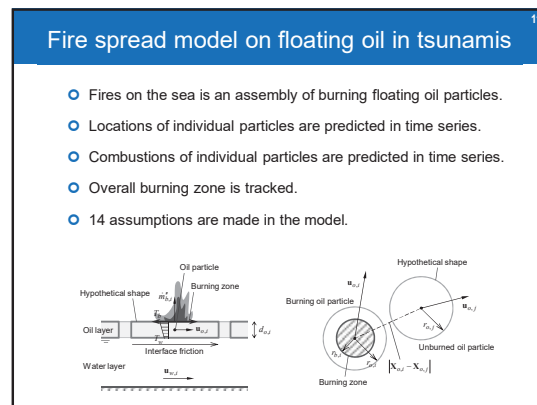
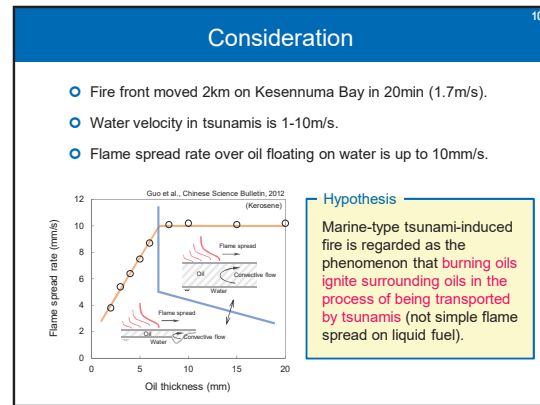
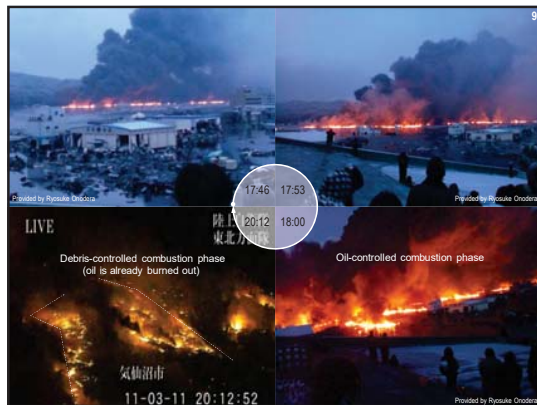
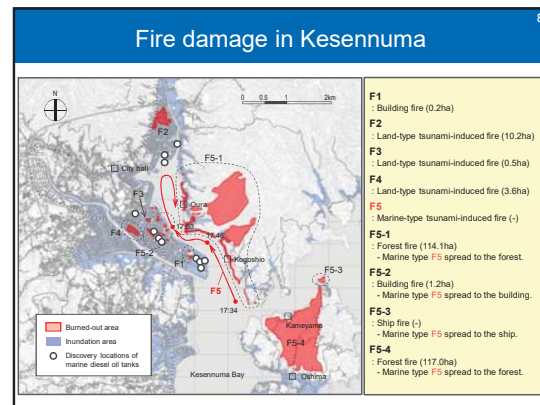
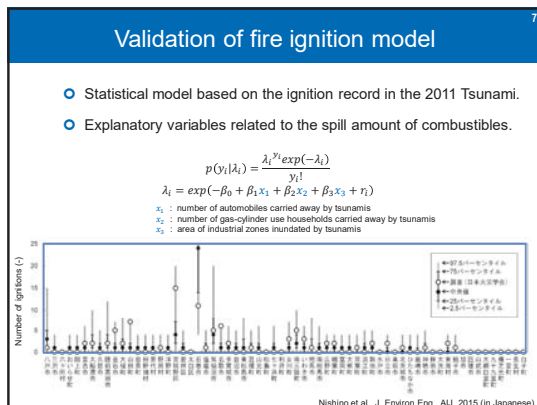
JSPS Grant-in-Aid for Young Scientists (A), FY2015-FY2017



## Validation of drift and accumulation model



Nishino et al., Fire Technology 2016





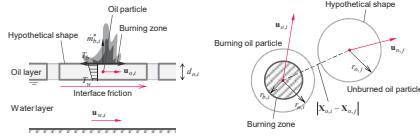
## Assumptions

13

- (6) Oil particles travel horizontally due to the interface friction and the turbulence in water flow.

$$\mathbf{x}_{o,i} = \mathbf{x}_{o,i}^l + \int_{t_l}^t \mathbf{u}_{o,i} dt + \sum_{k=1}^m \sqrt{24\kappa_i \Delta t} \left( \xi_i - \frac{1}{2} \right)$$

$$m_{o,i} \frac{\partial \mathbf{u}_{o,i}}{\partial t} = C_f \rho_{o,i} A_{o,i} (\mathbf{u}_{w,i} - \mathbf{u}_{o,i}) |\mathbf{u}_{w,i} - \mathbf{u}_{o,i}|$$

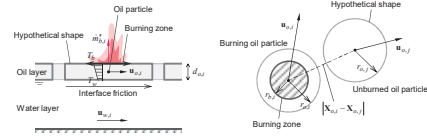


## Assumptions

14

- (7) Locations and time of first ignition is already known.  
(8) Combustion continues when thickness is not smaller than 1mm.  
(9) Mass loss rate due to combustion depends on the heat balance at the oil surface.

$$\rho_{o,i} \frac{\partial V_{o,i}}{\partial t} = -\pi r_{o,i}^2 \left[ \frac{\sigma T_b^4}{c(T_b - T_w) + L_v} - k_a(T_b - T_w)/d_{o,i} \right]$$



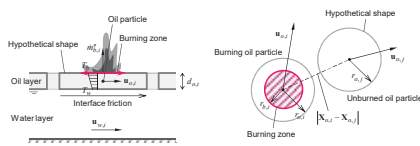
## Assumptions

15

- (10) Burning zones of particles spread in axial symmetry.  
(11) Spread rate of burning zones depends on the thickness.

$$\frac{\partial r_{b,i}}{\partial t} = \begin{cases} 0 & (d_{o,i} < 0.001) \\ 1.2d_{o,i} + 0.0016 & (0.001 \leq d_{o,i} < 0.007) \\ 0.01 & (0.007 \leq d_{o,i}) \end{cases}$$

The experimental data is approximated.  
(Guo et al., Chinese Science Bulletin, 2012)



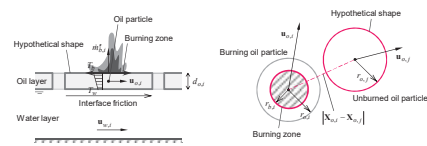
## Assumptions

16

- (12) Fire spread between particles occurs when burning zones contact with unburned particles.

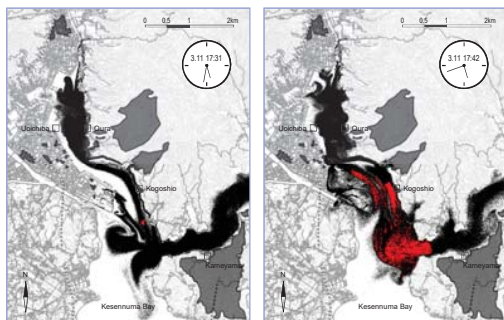
$$|x_{o,i} - x_{o,j}| \leq r_{b,i} + r_{b,j} \text{ and } d_{o,i} \geq 0.001 \text{ and } d_{o,j} \geq 0.001$$

- (13) Wind effect on the combustion is ignored.  
(14) Emulsification is ignored.



## Numerical analysis

17

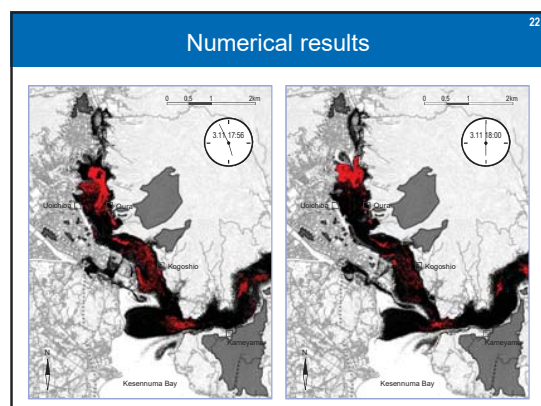
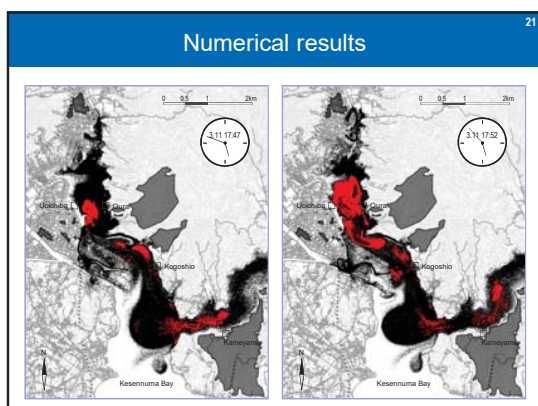
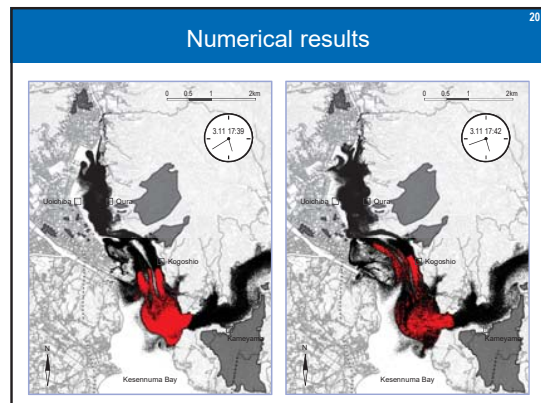
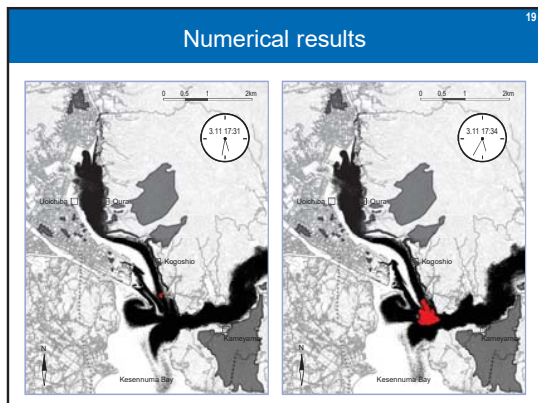


## Numerical conditions

18

Item		Settings
Simulation time		6h (2011.3.11 14:46-20:46)
Tsunami	Time increment	0.1s
	Mesh width	10m
	Fault model	Fujii et al., 2011
Oil (marine diesel)	Time increment	0.6s
	Initial volume of particles	0.001m <sup>3</sup>
	Number of particles	7,532,000 (=7,532kL) *
	Density of particles	814kg/m <sup>3</sup>
	Friction coefficient	0.006 (Lau et al., 1979)
	Spill locations	11 discovery points of tanks *
	Spill rate	0.2m <sup>3</sup> /s (convenient assumption)
Start time of spills		50min after the earthquake


\* Fire Departments of Kesennuma and Mototsu, 2012 (in Japanese)



23 Summary


- Modeling of fire spread on floating oil in tsunamis.
- Numerical analysis of tsunami-induced fire spread in Kesennuma.
- Qualitative trend of fire spread was well predicted.
- Future challenges
  - Model extension including the combustion of floating debris.
  - Radiation and plume modeling
  - Fire risk assessment of ports in future tsunami.





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Modeling the complexity of risk management in pipelines

F. Muñoz & M. Sanchez-Silva

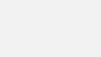
Department of Chemical Engineering & Department of Civil and Environmental Engineering  
School of Engineering






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Contents

- Objective and scope
- Assessment of systems subject to multiple natural hazards
- Pipeline evaluation: case study
- Cost-efficient design: Life-cycle cost analysis, evolution and changeability
- Conclusions

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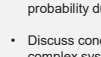
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Objective and scope

Objective and scope

- Present a comprehensive approach to modeling pipeline failure probability due to natural hazards (GeoRisk).
- Discuss conceptually some ideas regarding risk management of complex systems subject to highly uncertain events.

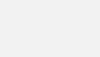
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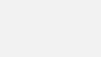
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Approach to modeling multiple hazards


Dimensionality of events & decision criteria

Definition of the decision space:  $\Omega = \{V, D, \mathcal{M}\}$

- Definition of the state variables (space):  
 $V = \{n, t, s\}$
- Managing problem complexity:
  - Nature and scope of the decision  
 $D = \{d_1, d_2, \dots, d_m\}$
  - Precision and relevance of the model  
 $\mathcal{M} = f(X_1, X_2, \dots, X_k)$

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Approach to modeling multiple hazards

Dimensionality of events

Definition of the state variables  $\{n, t, s\}$

Physical nature of event,  $n$ .

Antropic:


- Deficient operation
- Poor maintenance
- Terrorist attacks...

Natural origin:

- Seismic events (Peak Ground acceleration/displacement/velocity)
- Flooding (Water level and flow rate)
- Landslides (volume and mass displaced)
- Volcanic activity (seismic activity, pyroclastic flux, emissions)...

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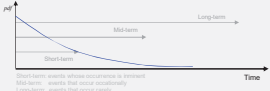
Approach to modeling multiple hazards

Dimensionality of events

Definition of the decision space  $\{n, t, s\}$


Physical nature of event,  $n$ .

Temporal dimensionality,  $t$ .



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Approach to modeling multiple hazards

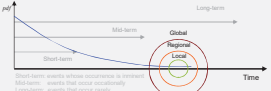
Dimensionality of events

Definition of the decision space  $\{n, t, s\}$

Physical nature of event,  $n$ .


Temporal dimensionality,  $t$ .

Size and spatial dimensionality,  $s$ .



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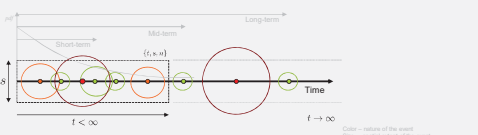
Approach to modeling multiple hazards

Dimensionality & decision criteria

Definition of state variables (space)  $\{n, t, s\}$


The scope of every study is defined within a space  $\{t, s, n\}$  such that  $t \in T$ ;  $s \in S$ ; and  $n \in N$

$T$ : Time dimensionality  
 $S$ : Space dimensionality  
 $N$ : Nature of the event



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Approach to modeling multiple hazards

Dimensionality of events & decision criteria

- Definition of the state variables (space)  $\{t, s, n\}$
- Managing problem complexity

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## Approach to modeling multiple hazards

### Dimensionality of events & decision criteria

Managing problem complexity  $\mathcal{M}$  and  $\mathcal{D}$

**System complexity:** systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.

Hierarchical representation for modeling complexity:  $\mathcal{M}$  and  $\mathcal{D}$

Lower Precision  
Larger number of interactions  
Difficult to model and understand  
Substantially large assessment cost

Higher Precision  
Limited interactions (independence)  
Available model descriptors  
Low assessment costs

Decision set  $D_1 = \{d_{1,1}, d_{1,2}, \dots, d_{1,m}\}$

Decision set  $D_n = \{d_{n,1}, d_{n,2}, \dots, d_{n,l}\}$

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## Approach to modeling multiple hazards

### Dimensionality of events & decision criteria

Managing problem complexity

**System complexity:** systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.

Structured hierarchical decision process

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## Approach to modeling multiple hazards

### Dimensionality of events & decision criteria

Managing problem complexity

**System complexity:** systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.

Structured hierarchical decision process

Initial evaluation level  
(defined by the resources available and the decision needs)

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## Approach to modeling multiple hazards

### Dimensionality of events & decision criteria

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Structured hierarchical decision process

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## Approach to modeling multiple hazards

### Dimensionality of events & decision criteria

Managing problem complexity

**System complexity:** systems consisting of many parts which interact in multiple ways leading to emerging patterns of behaviour.

Structured hierarchical decision process

Notes:

- Resources and evidence are synchronized with decision maker's needs.
- Decisions are controlled by the relationship between relevance and precision.
- It is not necessary to carry out a detailed analysis from the beginning.
- Resources invested in evidence collection can be optimized.

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## Approach to modeling multiple hazards

### Contents

- Objective and scope
- Assessment of systems subject to multiple natural hazards
- Pipeline evaluation: case study
- Cost-efficient design: Life-cycle cost analysis, evolution and changeability
- Conclusions

GeoRisk

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## Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards (GeoRisk).

**Project funded by ECOPETROL (Colombian Oil Company)**

**Main Research team:**  
 Asc. Professor Felipe Muñoz, PhD  
 Asc. Professor Nicolás Estrada, PhD  
 Asc. Professor Luis A. Camacho, PhD  
 Professor Bernardo Calcedo, PhD  
 Professor Mauricio Sánchez-Silva, PhD

**Local Experts:**

Professor Manuel García Universidad Nacional de Colombia  
Professor Jaime I. Ordoñez Universidad Nacional de Colombia

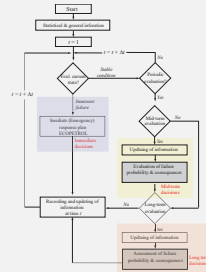
**International Experts:**

Professor KK Phoon (NUS-Singapore)  
Professor Joaquim Casal (UPB- Barcelona, Spain)  
Professor Emeritus Willy Alvarenga (Federal University of Rio de Janeiro)

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### Overall evaluation strategy



Notes:

- all three analysis are associated to different decision needs;
- the tools required in every case may be different;
- their evaluation does not occur necessarily at the same time.

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### Dimensionality of events & decision criteria

### Pipeline evaluation model and case study

	immediate evaluation	periodic evaluation	sporadic evaluations
Time span	Short-term	Mid-term	Long-term
	days	months	years
Examples	Pipe failure Active landslide Existing flooding	Potential landslide Local scour	Erosion Climate change Seismic activity Volcanic activity
Nature and scope of decision	Decisions focused on emergency response.	Decisions based on approximate physical models.	Long term strategic decisions.
Consequences	Direct (immediate) costs Brand impact	Impact on system operation, and stable state response	Catastrophic damage High impact/low probability

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## Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards.

Decision & evaluation space  $\{n, t, s\}$ 

1. Nature of the event ( $n$ ) – Landslides; i.e., soil mass movement that might cause a break-up of the pipeline.  
(scour and flooding were also studied)
2. Time window ( $t$ ) – events observed within a five-year period;
3. Spatial characterization ( $s$ ):
  - sector Medellín-Cartago (Col), length: 240 km
  - localized landslide events controlled by variations in the climatic conditions.



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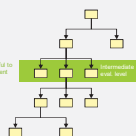
## Objective and scope

Develop an integrated model to evaluate the risk of pipelines subjected to multiple natural hazards.

### Structured hierarchical decision process

1. Decisions to be made:  $\mathcal{D}$ 
  - i) identify critical regions;
  - ii) preliminary *estimative of failure probability*;
  - iii) define inspection needs; and
  - iv) define further evaluation requirements.

1. The analysis is limited to landslides and scour problems (inhere we present only the landslide model).  $\mathcal{M}$



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### Pipeline evaluation model and case study

Required information:

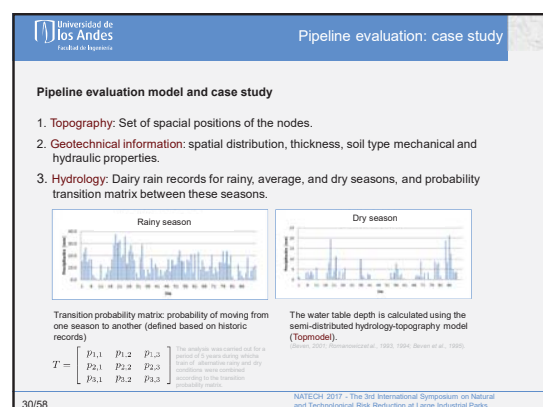
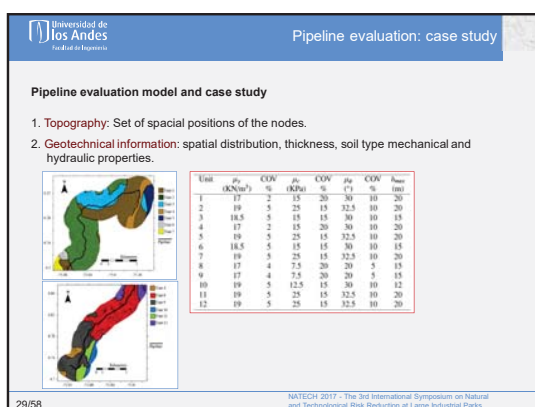
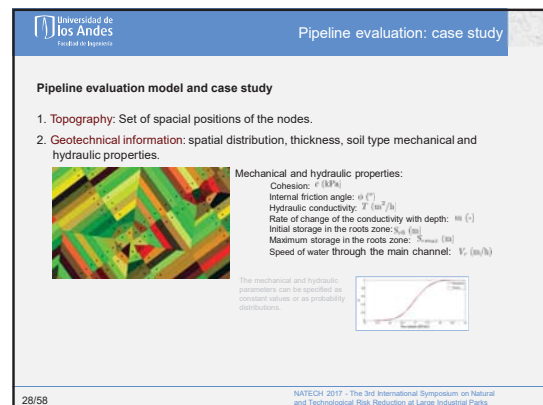
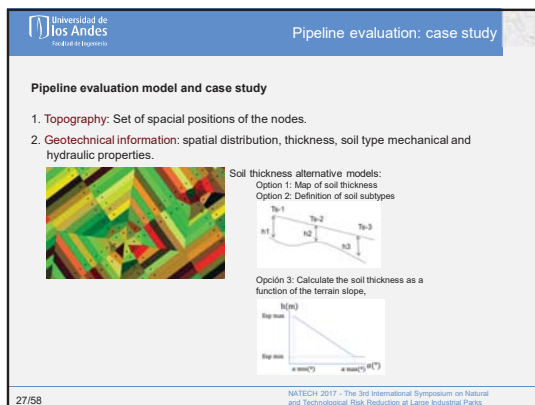
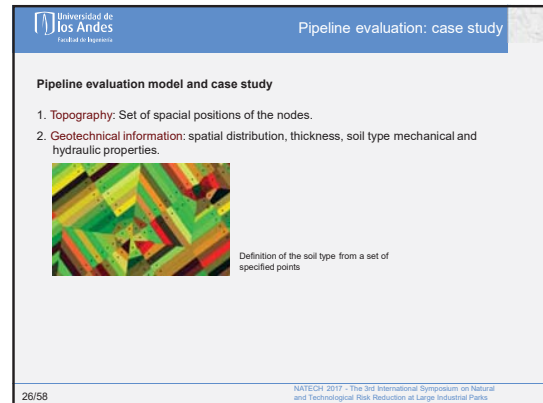
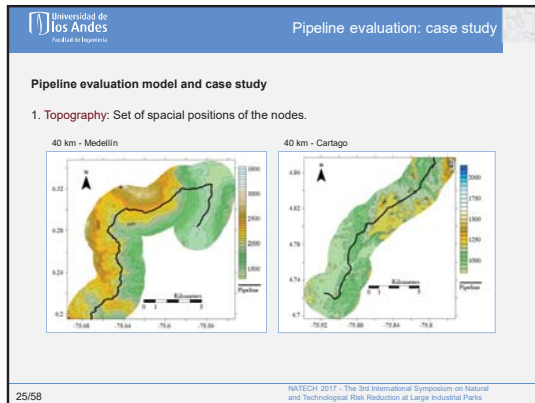
1. Topography.
2. Geotechnical information.
3. Hydrology.
4. Pipeline information.

Analysis and results:

1. Landslide probability
2. Pipeline failure probability

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Pipeline evaluation: case study

**Pipeline evaluation model and case study**

1. **Topography:** Set of spatial positions of the nodes.
2. **Geotechnical information:** spatial distribution, thickness, soil type mechanical and hydraulic properties.
3. **Hydrology:** Dairy rain records for rainy, average, and dry seasons, and probability transition matrix between these seasons.

Most critical water table

Average water table

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Pipeline evaluation: case study

**Pipeline evaluation model and case study**

1. **Topography:** Set of spatial positions of the nodes.
2. **Geotechnical information:** spatial distribution, thickness, soil type mechanical and hydraulic properties.
3. **Hydrology:** Dairy rain records for rainy, average, and dry seasons, and probability transition matrix between these seasons.
4. **Pipeline information:** depth of burial, diameter, wall thickness, material, etc.

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Pipeline evaluation: case study

**Analysis & results**

Computing the probability of landslide

1. **Planar failure surface:** stability analysis performed for every node.
2. **Rotational failure surface:** stability analysis performed for nodes whose thickness is above a certain threshold.

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Pipeline evaluation: case study

**Analysis & results**

Computing the probability of landslide

Heavy rainfall scenario  
40 km - Medellín

Dry scenario  
40 km - Medellín

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Pipeline evaluation: case study

**Analysis and results**

Computing the probability of landslide

Heavy rainfall scenario – correspondance with observed landslides

40 km - Medellín

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Pipeline evaluation: case study

**Analysis and results**

Pipeline failure probability

1. **Transversal alignment**
2. **Longitudinal alignment**

Maximum strains applied:  
(O'Rourke 1997)

$$\epsilon_t = \frac{F_t D_p^2}{3\pi t E D_p^2} \quad \epsilon_l = \frac{F_l D_p}{2\pi t E D_p}$$

Maximum possible strain:

$$\epsilon_{max} = \epsilon_t \sin \theta + \epsilon_l \cos \theta$$

where:

- $F_t$  or  $F_l$  - force per unit length (transverse or longitudinal)
- $D_p$  is the pipeline diameter,
- $t$  is the pipeline wall thickness,
- $E$  is the Young modulus and  $D$  is its diameter,
- $\theta$  is the angular difference between the centers of the landslide and that of the pipeline.

Strain capacity in tension:  $\epsilon_u = \frac{\sigma_u}{E}$

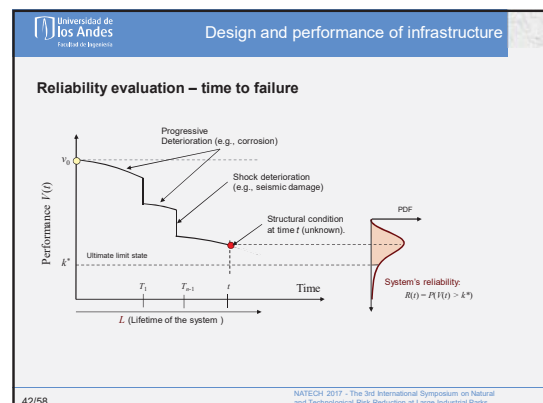
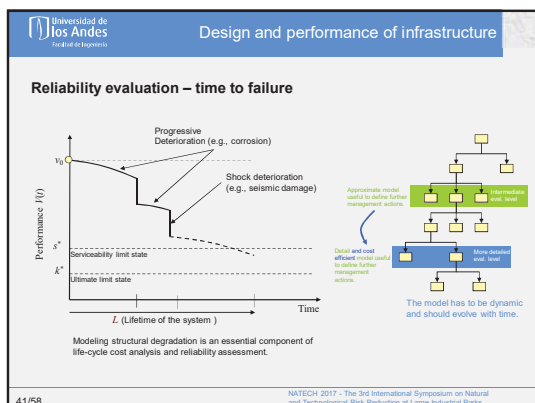
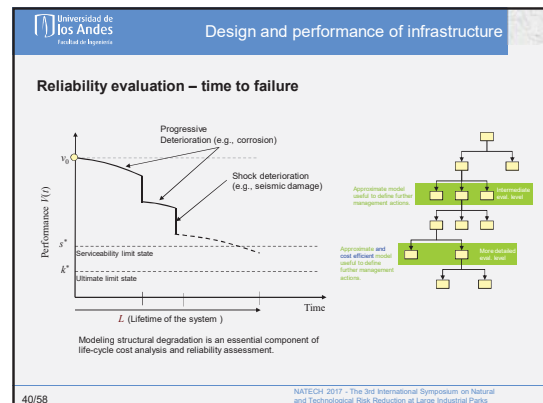
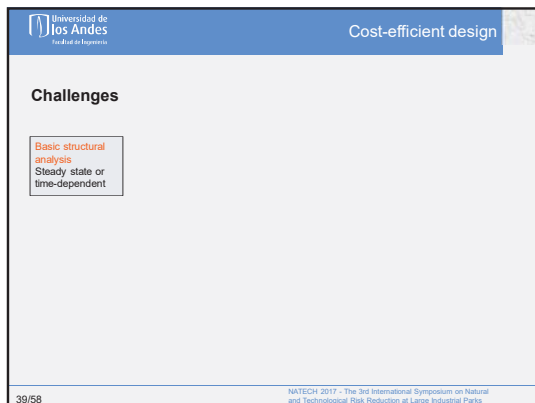
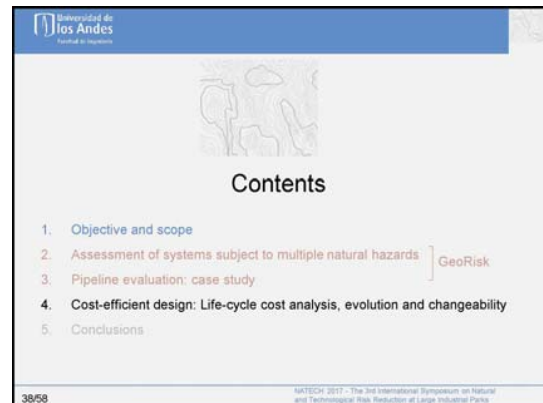
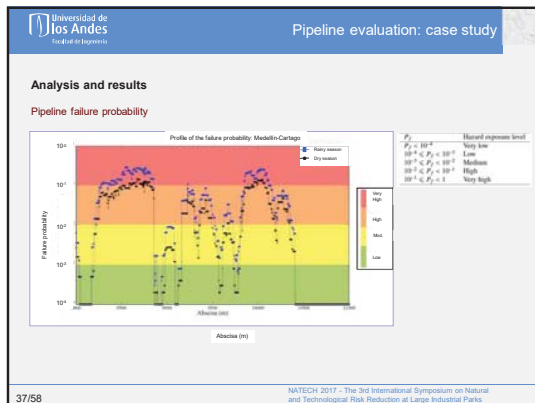
Strain capacity in compression:  $\epsilon_c = \frac{0.175 \sigma_c}{E \sqrt{2}}$

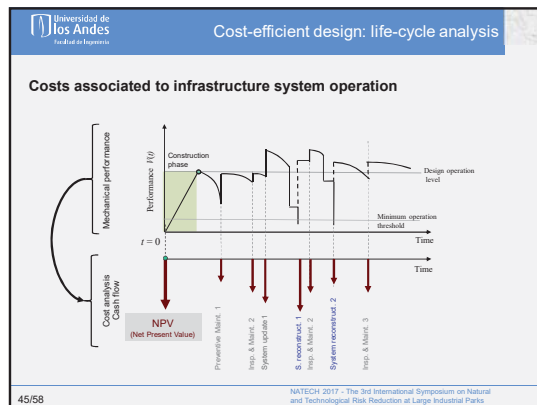
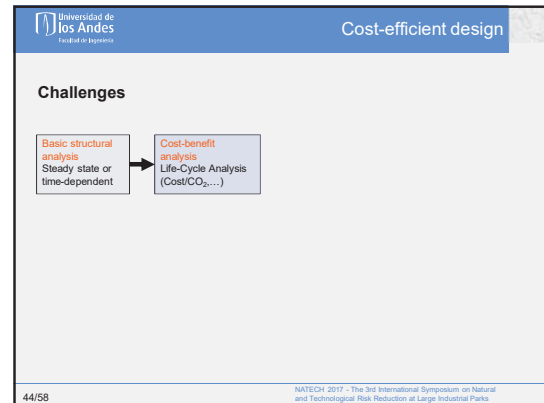
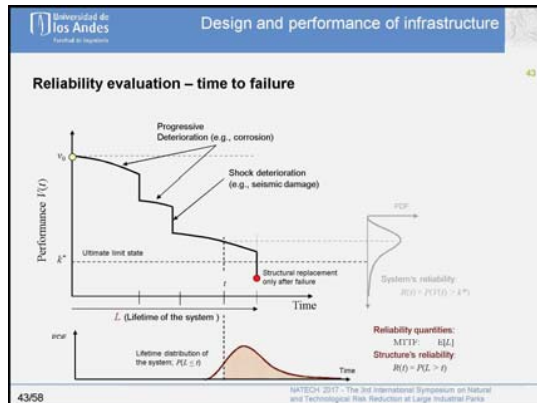
Failure occurs when:  $\epsilon_g - \epsilon_{max} < 0$

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### Cost-efficient design: life-cycle analysis

#### Cost-based optimization problem

Objective function:

$$Z(p) = B(p) - C_0(p) - C_L(p)$$

Note: this is evaluated at the end of the lifetime

Costs of losses (i.e., future investments)

$$C_L(p) = [C_d + C_{ins} + C_R + C_i + \dots]$$

Optimization  
(Maximize the expected NPV)

$$\max_p \{E[Z(p)]\} = \max_p \{E[B(p) - C_0(p) - C_L(p)]\}$$

$$= \max_p \{E[B(p)] - C_0(p) - E[C_L(p)]\}$$

Requires understanding and modeling the structural performance over time.

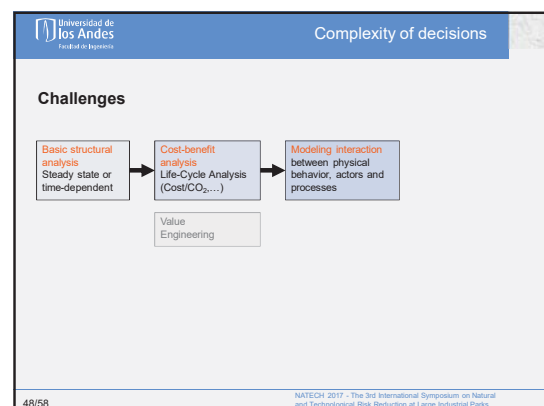
$t_m$  – time mission;  $\delta(t)$  – discount function.

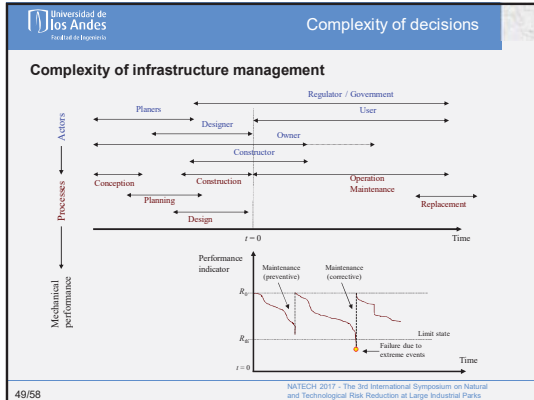
$$E[C_L(p)] = C_L(p) \int_0^{t_m} f_{C_L}(p, \tau) \delta(\tau) d\tau$$

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- ### Cost-efficient design: life-cycle analysis
- #### Limitations of Life Cycle Analysis: some key points
- Defining the **life of large infrastructure** is not always possible, specially for public projects; they last until a "political" decision is made.
  - The reference time is extremely long to make **accurate estimations of most parameters**.
  - Financial analysis** in current LCA is simplistic; e.g., future investments are fixed from the outset (estimating future cash flows is very difficult); and discounting is assumed to be constant.
  - Decisions about operation and management **can rarely be anticipated beyond reasonable (easy to handle) time horizons**; and change permanently as new information becomes available.
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### Complexity of decisions

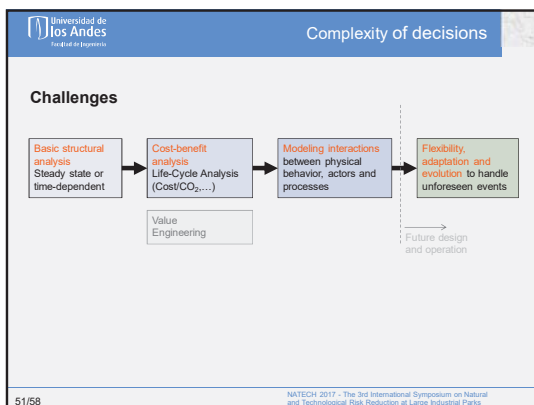
#### Important aspects in modeling the complexity of interactions

(ideas for discussion)

- Decisions on infrastructure operation are made based on a **combination of short, mid and long term reference time frames**.
- There are many actors whose **decisions, cannot be anticipated**.
- Maintaining and providing value to the system depends highly on the **perception and interests of stakeholders**.
- Large engineering projects need to be modeled as **multi-objective problems** where different dimensions and metrics need to be evaluated simultaneously.
- ....

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### Evolution of Design and LCA models

#### Key terms related to changeability

Concept	Definition	Ref.
Changeability	the ability to change, alter, or modify the system configuration with or without external influence after the system has been put in operation (deployed).	[18, 43]
Redesign	the process of evaluating and updating the system characteristics regularly to meet the changes in the demand or the environment.	[18, 34]
Adaptability	the system's ability to reconfigure itself after it has been put in operation (deployed), without external intervention.	[21, 43]
Flexibility	the system's ability (physically or managerially) to cope with uncertainty and change once it is in operation.	[44, 47, 52]
Resilience	the ability of a system to overcome undesirable events to continue operating with an acceptable (required) level of performance.	[6, 32]
Robustness	the ability of a system to withstand events without being damaged to a level that is disproportionate to the original cause.	[12, 14]

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### Complexity of decisions

#### Adaptability/flexibility: a perspective from Biology

- Live beings have survived for millions of years despite their **limited mid and long term capacity for making predictions**.
- Live beings can manage unplanned events and challenges **depending only on their flexibility and ability to modify its structure**.
- Adaptability (i.e., evolution) is designed to **be in-effective in a short run** (i.e. introducing mutations very often will only take you out of the current-local optimality);
- Evolution is effective in a long-run (**explores the solution space** and allows for the features that will be helpful if the environment changes). Note that adaptability of species occurs mostly across and not within generations.

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### Complexity of decisions

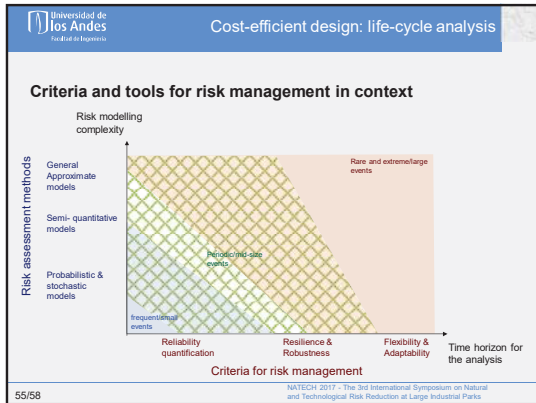
#### Adaptability/flexibility within the engineering context

Adaptability/flexibility will include new objectives in the design and operation of engineering systems; for instance, it will aim at (for discussion):

- Differing unnecessary initial provisions**, with the respective costs; thus, reducing the uncertainty associated to decisions;
- Having the flexibility** (physical and managerial) required to cope with unknown scenarios more effectively.
- Avoiding the concept of optimality** in the traditional sense; aiming only at best decisions (adding or preserving value) with the information available at every decision point.
- Modifying its structure and management strategies** based on the **experiences and knowledge acquired over time**.
- ....

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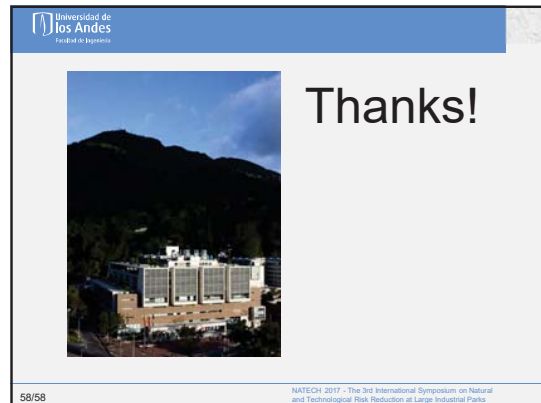
### Contents

1. Objective and scope
2. Assessment of systems subject to multiple natural hazards
3. Pipeline evaluation; case study
4. Cost-efficient design: Life-cycle cost analysis, evolution and changeability
5. Conclusions

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- ### Conclusions
1. GeoRisk is a tool that provides both a technical and conceptual framework to manage a diverse number of *Natech* problems.
  1. The design and operation of industrial infrastructure goes beyond technical issues. It is not possible to build efficient infrastructure without a broader approach to the problem.
  2. Any system (engineered or not) may not be able to fulfilling its purpose if it does not improve its ability to cope with new information (e.g., new demands), learn and improve its capabilities, and adapt its structure to be more efficient.
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### Pipeline evaluation: case study

#### Scope of event decisions

Temporal dimensionality

Description	time	Event	Approach	Mechanistic & prob. approach
Frequent events	$t = 0$	$t \in T_1$	Reliability based	Stochastic & Managerial approach
Rare events		$t \in (T_2 \setminus T_1)$	Resilience/Robustness	
Extreme events	$t \rightarrow \infty$	$t \in (T_3 \setminus T_2)$	Flexibility/Adaptability	

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## Radiation Measurement for Protection of Children in Fukushima

**Takeshi Komino**

General Secretary, CWS Japan

SG/Executive Committee, Asian Disaster Reduction and Response Network

Regional Steering Group, World Humanitarian Summit Asia

Co-Chair, Humanitarian Policy and Practice Advisory Group at ACT Alliance

Board Member, Core Humanitarian Standard

Secretariat, Japan CSO Coalition for DRR



## CWS Global Network



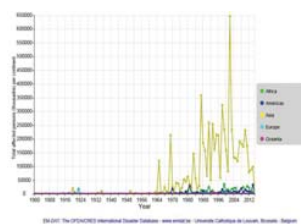
## CWS Japan Operation Pillars



## Disaster Trends

From UNISDR...

1. **Downward trend in mortality risk** due to enhanced capacities in early warning, preparedness and response.
2. **Upward trend in economic loss and damage** due to increase in exposure and vulnerability to natural hazards.
3. **No sufficient attention, capacity and investment to address underlying risk drivers** (unequal economic development, poorly managed urbanization, climate change)



## Sendai Framework for DRR 2015-2030

- **1.5 billion people** were affected by disasters in various ways.
- At Technical Hazard working session at WCDRR, participants called for **proactive risk assessment, and transparent disclosure of risks**.
- Sendai Framework's priority of areas:
  - 1. Understanding disaster risk;
  - 2. Strengthening disaster risk governance to manage disaster risk;
  - 3. Investing in disaster risk reduction for resilience;
  - 4. Enhancing disaster preparedness for effective response, and to "Build Back Better" in recovery, rehabilitation and reconstruction.
- Clear focus on **risk identification and mitigation**.



## Experience from Japan

- **Nuclear power plant meltdown** at Fukushima Daiichi Nuclear Power Plant
- **Many lessons** are drawn including:
  - Safety myth
  - Emergency evacuation
  - Information management
  - Critical infrastructure such as hospitals
- How are these lessons mitigating the **future risks**?



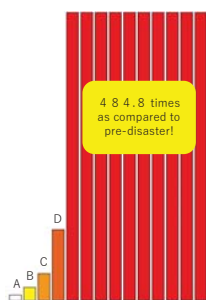


## Sharing Lessons and Protecting the Vulnerable



## Contamination Level

- A Air contamination level before the accident in Fukushima city **0.05  $\mu\text{Sv/h}$**
- B International standard on exposure limit **1 mSv/y = 0.114  $\mu\text{Sv/h}$**
- C Ministry of Environment's target after decontamination **0.23  $\mu\text{Sv/h}$**  (1.6 hours inside, 8 hours outside)
- D Designated high-radiation area **1.3 mSv/3 months = 0.6  $\mu\text{Sv/h}$**
- E The highest figure after the accident in the city **24.24  $\mu\text{Sv/h}$**



## Decontamination in Fukushima City 2016.10

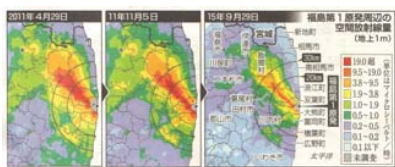


## How Contamination is Measured



2,700 units placed in Fukushima prefecture (in the city, 368 units)

Does this help to protect the future generation?



## Thinking about Well-being of Children

In 2014, Fukushima Prefecture saw limitation in promoting the health of children only with exercise inside (e.g. rise in obesity rate), so outside activities have started to be promoted.



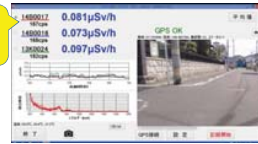


## Measurement for Protection of Children



1 m  
50 cm  
10 cm

1 m  
50 cm  
10 cm



Concrete roads – contaminated particles are washed away by rain, so lower figures

Lower than Ministry of Env. Standard  $0.23 \mu\text{Sv/h}$

Soft-surfaced sidewalk – contaminated rain is soaked inside, thus higher figures

Higher than designated high-radiation area  $0.60 \mu\text{Sv/h}$



It's not possible to use high-pressure decontamination for high contaminated rubber sidewalks.



Somehow, higher figures around the trees...

## Measuring your Exposure

### Glass Badge

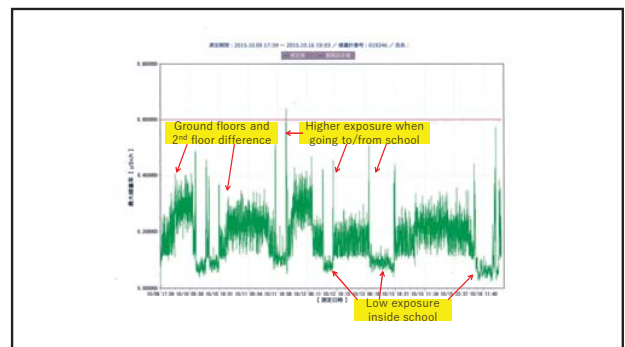
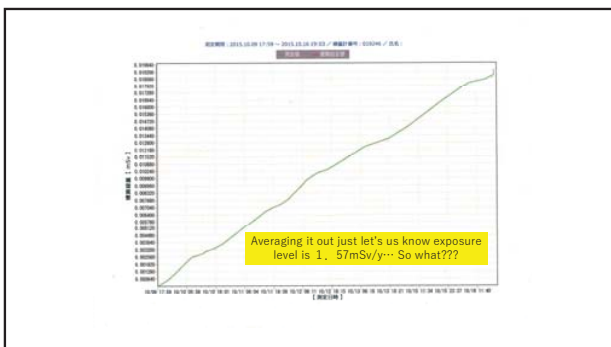
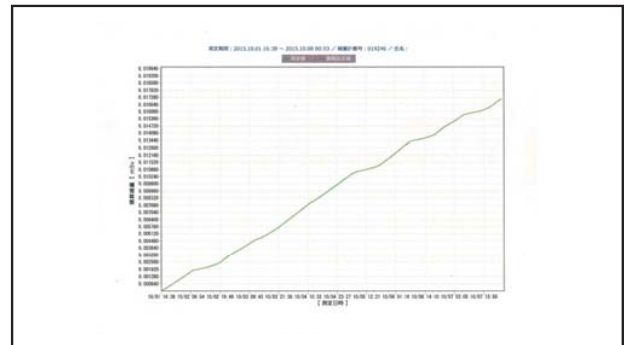
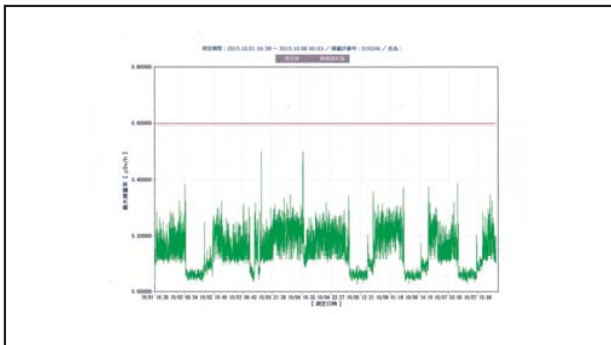
Local government lend to interested citizens. Then notifies accumulated exposure within 3 months period.



### DOSE e NANO

Provided by Shalom for interested citizens. Measured every minute, results are presented as accumulated figures in 6.25 days).








Decreasing exposure depends on accurate measurement !  
 ↓  
 Average results don't give you any action tips...



### Summary

- Many lessons – not political, it's linked to human lives
- Protection can only take place with human centered approach (limitation to one size fits all approach by the government)
- Protection by the people, for the people



Annex 4:

Number of Participants per Country  
and Participant Affiliations

Country	No.	Participants	Affiliation
<b>Afghanistan</b>	1	Marina Hamidzada	DPRI
<b>Bulgaria</b>	1	Toma Stoyanov	Kyoto University
<b>China</b>	1	Liuyi Zhang	DPRI
<b>Colombia</b>	4	Jaime Pacheco	First Secretary of the Colombian Embassy in Japan
		Felipe Muñoz	Universidad de los Andes
		Mauricio Sánchez	Universidad de los Andes
		María Camila Suarez Paba	DPRI
<b>Egypt</b>	2	Ahmed Ibrahim	Kyoto University
		Mohamed Abdel	DPRI
<b>Germany</b>	1	Uta Reichardt	DPRI
<b>India</b>	1	Sandhya Babel	Thammasat University
<b>Italy</b>	4	Valerio Cozzani	Università di Bologna
		Ernesto Salzano	Università di Bologna
		Elizabeth Krausmann	Joint Research Center, European Commission
		Giuseppe Aliperti	DPRI
<b>Japan</b>	16	Kaoru Takara	DPRI
		Ana Maria Cruz	DPRI
		Shin-Ichi Aoki	Osaka University
		Naomi Kato	Osaka University
		Daniel Cardoso	Osaka University
		Tomoaki Nishino	Building Research Institute
		Takeshi Komino	CWS
		Hirokazu Tatano	DPRI
		Takashi Kumagai	DPRI
		Kazuyoshi Nishijima	DPRI
		Alexander Guzman	Ritsumeikan University
		Atsushi Aoyama	Ritsumeikan University
		Dewi Dimyati	Kyoto University
		Kaori Horikomi	DPRI
		Sasha Yoshioka	Kyoto University
		Hitomu Kotani	DPRI
<b>Mexico</b>	1	Irasema Alcantara-Ayala	National Autonomous University of Mexico (UNAM)
<b>Philippines</b>	1	Angelica Baylon	MAAP
<b>South Korea</b>	1	BonJun Koo	DPRI

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## WORKSHOP ON TOOLS FOR NATECH RISK MANAGEMENT

